Net Neutrality and Investment Incentives:
An empirical analysis

Selma Grønningsæter

Masteroppgave

Masteroppgaven er levert for å fullføre graden

Master i samfunnsøkonomi

Universitetet i Bergen, Institutt for økonomi

[June 2022]

UNIVERSITETET I BERGEN

Foreword

To work with this thesis has been both an interesting and educational experience. It has also not something I could have managed on my own without the brilliant support of my two supervisors Eeva Mauring and Thomas de Haan, who kept me on track. Without them this thesis would have looked very differently.

I would also like to thank my family for always being available and supportive with motivating words. Especially my sister Ylva, who always answered my many phone calls and helped keep me calm when I needed it the most.

And finally, I would like to thank Niko for the long days keeping me company on Zoom as we both worked. You kept me structured.

Abstract

This thesis looks at the effect that the removal of Title II regulations on the Internet service providers under the Restoring Internet Freedom Order of 2018 had on Internet service provider's incentives to invest in their capacity.

I have found that contrary to the arguments used by the FCC (2018) in their choice to remove the regulations that there was no evidence that the removal has caused an increase in investment. Instead, using a difference-in-difference method and by using European Internet service providers as the counterfactual control group, I found that investment has decreased following the net neutrality removal.

This thesis looks at the capital expenditure by the Internet service providers over the period of 2004-2020, but the data sample only includes annual data points which is a weakness of this analysis and means that any effect found might be over- or underestimated. Because of this, this thesis will also be using Choi and Kim's (2010) model that examines the effect of net neutrality on investment incentives. By using their model, I argue that the reason for the fall in investment might have been caused primarily by the effect that any increase in speed will lower the content provider's willingness to pay to achieve first priority on the delivery of their content as well as an effect of increased content request rate, high bargaining power for the Internet service provider and low product differentiation. But I can not say anything about the strength of these effects.

Table of Content

Table of Figures

Table of Tables

1.0 Introduction

Have you ever been annoyed at seeing content you want to access stuck behind a buffering symbol? You might not have noticed if an email that was sent to you arrives a few seconds late, but if the sound on your important Zoom call is lagging, you definitely notice. But what if Zoom pays to speed their content up so that you no longer experience any lagging? Would this allow Zoom to dominate over competing sites like Skype and Microsoft Teams? Would these competitors also have to pay to be able to compete with Zoom on a level playing field? And what would happen to smaller competitors that can not afford to pay this price? All of these questions are part of the ongoing debate over net neutrality and how the future of the Internet should look like.

Net neutrality is the principle that Internet service providers should not discriminate between content from content providers and give consumers equal access to all legal content regardless of which website it is from. If we for example imagine that the Internet works as a motorway, where each websites' content has equal delivery speed. But the road is controlled by Internet service providers who can at any moment change how that road operates by allowing some sites to move over to faster lanes or by disallowing others to travel on the road altogether. Internet service providers have long argued that by banning their ability to charge the content providers for their bandwidth usage and offer faster lanes for the one that can afford it, they are harming innovation and investment (Buckley 2017, Cohen 2017). AT&T, CenturyLink, and USTelecom all commented on the removal of the 2015 net neutrality regulations arguing that the net neutrality regulations had served no beneficial purpose, and suppressed investment, that the Internet had never been a neutral place, and that the FCC had overreached its power (Eggerton 2017).

In 2018, the Federal Communications Commission (FCC) removed the United States' previous net neutrality regulations. The FCC used the same arguments as the Internet service providers by arguing that the removal of the previous net neutrality regulations Internet service providers would increase innovation and investment (FCC 2018). An important question is whether this claim of increased innovation has any merit.

In this thesis we will be looking at capital expenditure spending in the U.S. in the period of 2004-2020 to find out the effects that the 2018 removal of net neutrality had on the investment incentives of Internet service providers using a difference-in-difference method and using Europe[1] as the control group.

This analysis is built upon a limited data set with a short treatment period because of this this thesis will also be using Choi and Kim's (2010) model that examines the effect of net neutrality on investment incentives to discuss any effects that we find.

[1] Europe will in this thesis mean every European country excluding Turkey, Ukraine, Belarus, Iceland, and Russia as we are lacking data for those countries.

2.0 Net Neutrality

2.1 History of net neutrality

In 2003 Tim Wu published a paper about the future of network regulation in which he coined the term "network neutrality", later shorten to net neutrality, at a time where broadband providers were blocking services like VPNs on their networks (Wu 2003).
Wu was worried that the regulators would have to deal with a rising number of conflicts between the private interests of Internet service providers and the public's interest in the next decades over an increasingly competitive innovation environment centered on the Internet and constructed an approach to dealing with it by making a proposal for network neutrality.

Since then, there have been vocal arguments both for and against regulating the telecommunication sector. When the term was originally introduced in 2004 it was before sites like Facebook, YouTube, and Netflix existed, and dial-up were still the requirement to access sites (Schultz 2014). Nowadays we are requiring more and more download speed as the content we consume requires more bandwidth to function (FCC 2020).

Opponents of net neutrality argue that net neutrality harms the telecommunications sector by disincentivizing investments in infrastructure as sites that continue requiring high amount of bandwidth does not pay for it (Faulhaber 2010, Litan & Singer 2007). While proponents argue that without net neutrality innovations online will slow down and Internet service providers will have too much power over the Internet access from ordinary consumers (Greenstein, Martin & Valletti 2016, Wu 2006).

2.2 Regulation in the U.S.

In the U.S. net neutrality regulations has become a highly polarizing and politized subject with vocal voices on both sides of the debate that seems to have split along party lines with Democrats for more and stronger regulations and Republicans against (Nilsen 2019).

USA's first tries at an anti-discrimination regulation came under the Bush administration in 2005 when the Federal Communications Commission (FCC) banned any Internet service provider from blocking any content that was not illegal nor prevent any consumer from connecting a device of their choosing to their own Internet connection. In 2008 the FCC tried using this policy to order Comcast to stop slowing down connections that used the peer-to-peer file-sharing software BitTorrent. But Comcast sued this order arguing that the FCC were overstepping their bounds and had no authority to enforce the net neutrality regulations. The courts agreed, ruling in favor of Comcast (Finley, 2020).

In 2010 under President Obama, the FCC tried a new pass at net neutrality regulations and introduced the Open Internet Order as a means to strengthen regulations on ISPs. Same as before it banned blocking of lawful content but expanded on the previous rules by also banning unreasonable discrimination when transmitting content and called for higher amount of transparency from the ISPs (FCC 2010). The vote for the new regulation had been split along party lines with a 3-2 vote, and Politico could report that less than an hour after the FCC had approved of the Open Internet Order, Republican lawmakers had begone working on a repeal (Romm 2010). Even with these pushbacks the Open Internet Order would stand until January of 2014 when a federal court ruled against the FCC in the case of Verizon v. FCC. The court declared that the agency didn’t have the authority to impose net neutrality regulations on broadband providers as they were not classified as common carriers under Title II of the Communications Act (Crews Jr. 2014).

Later that year, a push came for stronger net neutrality regulations after the FCC received 21.9 million comments worrying over a proposal put forward by the FCC of granting ISPs permission to create Internet “fast lanes” (Finley, 2020).
The FCC changed tactic and in February of 2015 they passed the Title II Net Neutrality Rules that went into effect in June of the same year. In the new rules the ISPs go from belonging to Title I of the Communications act of 1934 and being classified as general provisions to being put under Title II and classified as Common Carriers. This came with much harsher regulations and stronger overview from the FCC, though with fewer obligations than landline telephone operators (FCC 2015).
The FCC was again sued by telecommunications firms, but the court sided with the FCC and ruled that the new classification was legal (Finley, 2020).

In January 2017, the FCC faced changes as newly elected President Trump appointed Ajit Pai as the new chair of the agency. Ajit Pai quickly established that he was against the 2015 net neutrality order and announced in April of the same year that he planned to revers it (Finley

2020). On the 11th of June 2018, Ajit Pai announced the officially repeal of the 2015 net neutrality rules following a close vote by the FCC commission (Collins 2018).

After a failed lawsuit, brought forth by twenty-one state attorneys general, decided mostly in favor of the FCC in 2019 an important point was made. The fight to keep the national rules were lost but the court ruled that the agency could not override state-level net neutrality laws and several states were quick to respond with passing net neutrality laws (Finley 2020).

With the 2020 presidential election came a new President. The newly elected President Biden was quick in urging the FCC to restore the Obama-era net neutrality rules, doing so in July of 2021 even before appointing a new chair (Kelly 2021). Net neutrality has once more come into focus as President Biden remains vocal on the issue, but no new regulations has been introduced (Reardon 2022).

2.3 History of Net Neutrality in Europe

2.3.1 European Union

In the European Union the basic framework for net neutrality is laid down by Article 3 of EU Regulation 2015/2120, but the debate started earlier. The issues surrounding regulation on ISPs in the EU started around 2005. This was when problems arose by network operators having started to explore increased commercial opportunities and begone to prioritize certain content over others. To combat these practices a new Telecom Framework was discussed at the regulatory EU level in 2007 (Gadringer 2020). Following this, countries in the EU started to adopt net neutrality regulations but several countries ran a self-regulatory approach on how to regulate the ISPs compared to the U.S. This created problems and in 2012 the Body of European Regulators for Electronic Communications (BEREC) were commissioned by the EU to survey how European ISPs managed the traffic on their networks. The survey showed that every fifth subscriber of fixed Internet connection experienced restrictions on their usage of Internet connection (Sørensen 2020). But it wasn’t until 2015 that EU got the Telecom Single Market-Regulation-Directive and adopted a uniform provision on net neutrality covering all EU countries, that went into effect in April 2016 (Rundfunk und Telekom Regulirungs-GMBH 2021). The new regulations were criticized for being too weak as it offered loopholes that ISPs could exploit in discriminating between content providers (World Wide Web Foundation 2015).

In 2019, BEREC chose to update the 2016 guidelines and published the final version of the new guidelines in 2020 (BEREC 2020). One of the biggest changes introduced were the updated rules that tighten down on zero-rating, and when companies were allowed to offer it. Though it did not ban the offering of it. However, in 2021 BEREC announced that it would look more into the zero-rating rules as calls were being made arguing for stricter restrictions (BEREC 2021).

2.3.2 Norway

Norway was early in its introduction of net neutrality regulations, as the country already established guidelines for net neutrality in 2009. But it differs from the U.S. and the EU in that it regulated the 2009 guidelines in a co-regulatory approach instead of regulating the industry directly. The guidelines included rules against blocking and throttling of traffic from content providers and were believed at the time to be enough to protect net neutrality in Norway (Post- og Teletilsynet 2009). A year after Article 3 of EU Regulation 2015/2120 went into effect, Norway decided to follow and adopted the EU regulations into law in 2017. These regulations tighten the existing Norwegian net neutrality policies, as both set of regulations covered rules surrounding transparency, banning blocking, and throttling of lawful data (Sørensen 2020)

2.4 Review of empirical works around net neutrality

Several economists have looked at the questions posed around the net neutrality debate, about its impact on network investment and its effects on both ISPs and CPs innovation incentives. This has often been done without using empirical observation to support their theories and hypotheses on both sides of the net neutrality debate. This is especially notable before the 2017 rule change, and there seems to be only limited empirical data that have been added to the literature during and since 2017 (Hooton 2020).

Bourreau, Kourandi and Valletti (2015), Choi and Kim (2010), and Gans (2014) used models to theorize the effect of net neutrality on investment incentives. Bourreau (et al. 2015) uses a model with two competing Internet platforms and a continuum of CPs and studied the effect of net neutrality on capacity investments in the market for ISPs. They found that ISPs would invest more in network capacity without net neutrality than under, since they could be partly

compensated for their investments by the additional revenues that they can extract from the Content Providers through priority fees to access the fast lane.
While Choi and Kim (2010) use a simple model based on the queuing theory to capture congestion in the network that we will look at in more detail in chapter 3.
Gans (2014) used a simple model to illustrate the effect of different strengths of net neutrality regulations. He looked at how different strengths of net neutrality regulations shifted surplus from ISPs to content providers which had consequences for the CPs investment but did not find a mechanism where net neutrality regulations would have an adverse impact on ISP investment.

For empirical studies on the effect of net neutrality Ford (2017) found that the regulation had a negative effect on the incentives to invest by using a difference in difference causal impact model. But Ford placed the treatment time at the 2010 Open Internet Order regulation and argued that the reduction in investment he found for the period after 2010 could directly apply to the 2015 Title II ruling. This was even though during the 2010 Open internet Order ISPs where not put under Title II and thereby were under softer regulation than what the 2015 regulation imposed (Hooton 2020).

In 2017 the Free Press Action Fund using SEC filings showed that capital expenditure by publicly traded broadband providers where up 5.3% when comparing the percentage change of 2015-2016 with 2013-2014, but they have not done a statistical analysis that proves that this change is caused by net neutrality and not something else. While Hooton (2017) found no statistical evidence that support that net neutrality harmed investment incentives, but the author himself noted that there were clear issues with the quality of some of the data employed in the analysis. Ford (2019) argued that Hooton (2017) had not published what countries were contained in his control group and that his choice of dependent variable was heavily flawed. In 2020, Hooton came out with a new paper where he again examined the impacts of the 2010 and 2015 net neutrality regulation on investment for the telecommunications industry and found no evidence of any impact. Hooton (2020) employed a difference-in-difference model and used the average across all non-telecommunications firms as his control group similar to Ford (2017), but once more received heavy criticism for his methods (Ford 2021). Hooton's (2020) article have in June of 2020 received an expression of concern from the journal that it was originally published in, based upon selection bias because two of the largest ISPs in the United States -AT&T and Verizon – were not included in the analysis, with potentially significant impact on the results (Bohlin 2020).

3.0 Model

Before we can discuss the data set and any effect that we find we first need to build up the framework that we will later use to analyze the results of the difference-in-difference model. To do that we will look at the model made by Choi and Kim (2010) where they theorized a model in which they analyze if there is an effect on Internet service provider's (ISP's) investment incentives from net neutrality regulation.

The model in Choi and Kim (2010) is based upon a monopolistic Internet service provider with two content providers (CP1 and CP2) who compete against each other to deliver content to end consumers. In this model the end users do not pay the content providers any direct fee for this content but do pay the ISP a price of a to access its network connection. Each consumer has a content request rate of λ_1 that combined represents demand intensity.

The model assumes that each consumer has a demand for one of the two CPs and gets a utility of $u(\lambda) = v$, where v is sufficiently large so that the market is fully covered.

The consumers are heterogeneous in their preferences towards one of the two content providers in a Hotelling manner, meaning that the consumers view the content providers products or services as equal in the value that they bring the consumers. To simplify the model, each content provider is placed on each end of a line whose length is normalized to one. A consumer located at x pays the transport cost of tx and $t(1-x)$ to consume either's content. Here t can represent the degree of product differentiation between the content from the two content providers.

The two content providers can't take direct payment from the end users but earn revenue from advertisements; they earn a markup from each consumers visiting their content. This is represented by $m_i = r_i - c_i$, where r_i is the revenue made from advertisement and c_i is the cost of serving each consumer's request, and where $m_1 \geq m \geq m_2$.

The network is limited by its network capacity, μ, on how fast it delivers the content from the providers to the end user so there is a wait time of $w_i = \frac{1}{\mu - \lambda}$. The wait time increases with the content request rate and decreases when the ISP increases its network capacity and where $\mu > \lambda$.

In a system with net neutrality regulation the ISP is not allowed to discriminate on the delivery time from each content provider, meaning that the wait time will be only limited by network capacity and demand intensity.
Without net neutrality regulation the ISP is free to sell the right to be served ahead of the other to either content provider. In a discriminatory network (meaning a network without net neutrality regulations) consumers who request content from a content provider without priority access faces a longer wait time than if they had request it from the content provider with.

$$w_1 = \frac{1}{\mu - \lambda_1} < \frac{\mu}{\mu - \lambda} \frac{1}{\mu - \lambda_1} = w_2 \qquad (1)$$

Here λ_1 stands for the total amount of traffic from consumers who have requested content from the content provider with priority access. The consumers who do not request content from a provider with priority is placed behind the consumers who do, increasing their wait time. An important thing to note here is that as network capacity increases the reduction in waiting time that consumers get from requesting content with priority access becomes smaller.

$$\frac{\partial}{\partial \mu}(w_2 - w_1) < 0 \qquad (2)$$

3.1 Short-run equilibrium with net neutrality

Investments take time to plan, for Internet service providers any expansion in infrastructure will take time to implement, meaning that in the short run we can assume that the ISP's network capacity is fixed and thereby exogenous.
If the ISP is under net neutrality regulations the end users can choose one of the two content providers without having to think about waiting time as it will be equal for both CPs.
The marginal consumer x^* who is indifferent between the two content providers satisfies the following equation

$$v - \frac{1}{\mu - \lambda} - tx^* - a = v - \frac{1}{\mu - \lambda} - t(1 - x^*) - a \qquad (3)$$

Where consumers who have a lower x than the marginal consumer chooses CP1 and those that have a higher x chooses CP2. Since these placements are placed in a Hotelling manner with two symmetrically positioned content providers, the marginal consumer is placed at the half way point between them at $\dot{x}$. For further scenarios we assume that each consumer's taste parameter x is fixed and only have that the middle consumer's (x=1/2) participation constraint that is binding. The ISP's profit maximization problem is therefore given by how much it can take in price from the end users in network access fee.

$$\max_{a} \pi_m = a \qquad s.t. \quad v - \frac{1}{\mu - \lambda} - tx^* - a \geq 0$$

(4)

We can derive this to get that the equilibrium network access fee and each content providers profit in a market with net neutrality regulation is

$$\pi_m^* = a^* = v - \frac{1}{\mu - \lambda} - \frac{t}{2}; \quad \pi_i^* = \frac{m_i}{2}\lambda \ for\ i = 1,2$$

(5)

3.2 Short-run equilibrium without net neutrality

We are assuming now that the more efficient content provider, CP1, has obtained first priority, meaning that its content will be served ahead of CP2's. We look at the marginal consumer at $\tilde{x}$, who is indifferent between the two content providers, and has the following equation:

$$v - \frac{1}{\mu - \tilde{x}\lambda} - t\tilde{x} - a = v - \frac{\mu}{\mu - \lambda}\frac{1}{\mu - \tilde{x}\lambda} - t(1 - \tilde{x}) - a$$

(6)

Since CP1 has first priority more consumers will want to switch over from CP2 to CP1 as wait time for CP2's content is higher than CP1's. This will increase the wait time for CP1 but CP2's wait time will worsen more as they are put behind the increasing wait time for CP1.

$$\frac{\partial w_2}{\partial \lambda_1} = \frac{\mu}{\mu - \lambda_1}\frac{1}{\mu - \lambda} > \frac{1}{\mu - \lambda_1} = \frac{\partial w_1}{\partial \lambda_1} > 0$$

(7)

The gap in waiting time between the two content providers widens as we get a positive-feedback loop when as consumers switch to CP1, they increase the waiting time for CP1 and thereby worsen the waiting time for CP2 more and making CP1 more attractive for consumers leading to more switching over to CP1. This can lead to a situation where all the consumers go to CP1. To ensure that this doesn't happen the model makes the assumption that the two content providers content are differentiated enough to prevent a corner solution:

$Assumption\colon\ t > \frac{\mu}{\mu-\lambda}2$

To create a stable interior market-sharing equilibrium between the two content providers and to create a condition whereby if the network capacity goes up less consumers go to the content provider with first priority the model makes the assumption that as long as $\mu > \frac{3\lambda}{2}$. Then the model will have a stable interior equilibrium with $\tilde{x} \in (\frac{1}{2}, 1)$ and the market share for CP1 will go down as ISP's network capacity increases, that is $\frac{d\tilde{x}}{d\mu} < 0$.

The profit for the ISP is therefore given by

$$\max_{\tilde{a}} \tilde{\pi}_m = \tilde{a} + f \quad s.t. \quad v - \frac{1}{\mu - \tilde{x}\lambda} - t\tilde{x} - \tilde{a} \geq 0 \tag{8}$$

Here we can see that the Internet service providers profit is the price that consumers pay to have access to its network connection plus f which denotes the revenue that it gets from the sale of first priority to CP1. Both content providers can compete to get this priority as each content provider knows that its market share will be $\tilde{x}$ if it acquires the priority right but $(1 - \tilde{x})$ if it doesn't, making the maximum willingness that it has to pay for this priority $m_i(2\tilde{x} - 1)\lambda$. Since $m_1 \geq m \geq m_2$ if the priority right is sold through a first-price ascending auction, CP1 will receive the priority with $f = m_2(2\tilde{x} - 1)\lambda$, which is CP2's maximum willingness to pay for the priority which is lower than CP1's maximum. If the ISP wants to extract all the surplus from CP1 it can do so by making sequential take-it-or-leave-it offers where the ISP first offer the rights to CP1 for its maximum willingness to pay, knowing that if CP1 does not accept then it can make another offer to CP2 for its maximum. To encompass the choices that the ISP can take when it comes to selling the priority including the above examples, we add the variable $\theta(0 \leq \theta \leq 1)$ which represents the ISP's bargaining power that measures the proportion of rent extraction from CP1 so that the price for first priority is

$$\begin{aligned} f &= \theta m_1(2\tilde{x} - 1)\lambda + (1 - \theta)m_2(2\tilde{x} - 1)\lambda \\ &= (m_2 + \theta\Delta_m)(2\tilde{x} - 1)\lambda, \end{aligned} \tag{9}$$

where $\Delta_m = m_1 - m_2 (\geq 0)$ and $\theta \in [0,1]$. As the ISP's bargaining power increases so does the priority price, that is, $\frac{\partial f}{\partial \theta} = \Delta_m (2\tilde{x} - 1)\lambda \geq 0$.

We can therefore express the ISP's profit in a market without net neutrality regulation as

$$\tilde{\pi}_m = \left(v - \frac{1}{\mu - \tilde{x}\lambda} - t\tilde{x}\right) + (m_2 + \theta\Delta_m)(2\tilde{x} - 1)\lambda. \tag{10}$$

When the ISP has assigned the priority to CP1 at the price f mentioned earlier, each content provider's profit will be given by

$$\tilde{\pi}_1 = m_1\tilde{x}\lambda - (m_2 + \theta\Delta_m)(2\tilde{x} - 1)\lambda; \quad \tilde{\pi}_2 = m_2(1 - \tilde{x})\lambda \tag{11}$$

If $m_1 = m_2$ then the ISP's bargaining power becomes irrelevant as both of the content providers make the same profit.

3.4 Long-run equilibrium with investment incentives

One of the main issues in the debates surrounding net neutrality regulations has been its effect on ISP's incentive to invest in their infrastructure. Critics claim that net neutrality would discourage investment leaving especially rural areas that are underserved. Kim and Choi (2010) use their model to examine the validity of such claims by investigating the marginal change in the ISP's profit with respect to the network capacity parameter μ for the two network regimes. Let $\Phi(\mu)$ be the cost associated with the capacity level of μ with $\Phi'(\mu) \geq 0$ and $\Phi''(\mu) \geq 0$. The ISP's choice of its optimal investment level will be determined at the point where the marginal benefit and the marginal cost with respect to its capacity level are equal, or where, $\frac{d\tilde{\pi}}{d\mu} = \Phi'(\mu)$ in the discriminatory network and $\frac{d\pi}{d\mu} = \Phi'(\mu)$ in the network with net neutrality regulations. The marginal benefit of capacity expansion can therefore be written as

$$\frac{d\pi_m}{d\mu} = \frac{da}{d\mu} = \frac{1}{(\mu - \lambda)^2} \tag{12}$$

and

$$\frac{d\tilde{\pi}_m}{d\mu} = \frac{d\tilde{a}}{d\mu} + \frac{df}{d\mu} = \left[\frac{1}{(\mu - \tilde{x}\lambda)^2}\left(1 - \lambda\frac{d\tilde{x}}{d\mu}\right) - t\frac{d\tilde{x}}{d\mu}\right] + 2(m_2 + \theta\Delta_m)\lambda\frac{d\tilde{x}}{d\mu} \tag{13}$$

Therefore,

$$\frac{d\tilde{\pi}_m}{d\mu} - \frac{d\pi_m}{d\mu} = \left(\frac{d\tilde{a}}{d\mu} - \frac{da}{d\mu}\right) + \frac{df}{d\mu}$$

$$= \left[\frac{1}{(\mu - \tilde{x}\lambda)^2}\left(1 - \lambda\frac{d\tilde{x}}{d\mu}\right) - t\frac{d\tilde{x}}{d\mu} - \frac{1}{(\mu - \lambda)^2}\right] + 2(m_2 + \theta\Delta_m)\lambda\frac{d\tilde{x}}{d\mu} \tag{14}$$

As you can see there are two effects to consider when evaluating the relative incentives to invest in capacity across the two regimes, those are the effect on end user access fee due to discrimination and the effect on the sale price of priority right.

First, capacity expansion affects the network access fee that the ISP can charge the end users, specifically the willingness to pay by the marginal end users. This network access fee effect is captured by the expression in the square brackets. Capacity expansion affects differently in the neutral network than in the discriminatory network: in the neutral network, meaning with net neutrality regulations any capacity expansion speeds up the delivery of content uniformly which does allow the ISP to charge more for access, as is captured in $\frac{1}{(\mu-\lambda)^2}$. But in the discriminatory network this expansion speeds up the delivery of content asymmetrically across the content providers, and therefore affecting the location of the marginal consumer type who is indifferent between the two content provider. This effect is captured in the equation by the first two terms in the square bracket. The first term is $\frac{1}{(\mu-\tilde{x}\lambda)^2}\left(1 - \lambda\frac{d\tilde{x}}{d\mu}\right)$ and measures the effect that the expansion has on the consumer's network access fee when the delivery speed of content has improved. You can split this effect into two parts where the first part $\frac{1}{(\mu-\tilde{x}\lambda)^2}$, measures the increases in the marginal consumer's willingness to pay for network access when they request content from the content provider with priority. The benefit that this user get is lower under the discriminatory network than under the neutral one as $\frac{1}{(\mu-\tilde{x}\lambda)^2} < \frac{1}{(\mu-\lambda)^2}$.

The reason for this is that the CP with priority delivery speed is already quick so that any beneficial effect of capacity expansion on this speed is relatively small.

However, there is a secondary effect where the expansion benefits the CP without priority more as the gap between the two CPs when it comes to delivery speed shrink as the reduction in waiting time that consumers get from requesting content with priority access becomes smaller, as shown with $\frac{d\tilde{x}}{d\mu} < 0$.

The change in the marginal consumer's willingness to pay due to this demand effect is captured by the second part with $-\lambda \frac{1}{(\mu-\tilde{x}\lambda)^2}\frac{d\tilde{x}}{d\mu}(> 0)$. It is also important to note that any capacity expansion decreases the transportation cost of the marginal consumer who requests content from the content provider with priority in the discriminatory regime. This saving will also increase the marginal consumer's willingness to pay for network access and is captured by the second term in the square bracket, $-t\frac{d\tilde{x}}{d\mu}(> 0)$. Because the benefit that the consumer get under the discriminatory regime from any capacity expansion is lower than under a neutral one, the combined effect of the square bracket term on investment is indeterminate. We therefore cannot tell unambiguously the relative size of this network access fee under the neutral regime and under the discriminatory regime.

Second, any capacity expansion also affects the sale price that the ISP can take of the priority right under the discriminatory regime. This effect is called the rent extraction effect and is represented by the last term in equation (14). As mentioned earlier, in a discriminatory regime any capacity expansion the benefits that the content provider with priority access gets is relatively small and thus holds a small value for the content provider. Any increases in capacity level weakens the amount of rent that the ISP can extract from the allocation of priority classes since the wait time difference between the two classes of content providers decreases as capacity levels rises.

To find out the overall effect of the incentives that the ISP has to invest you need to find out the relative magnitudes of these two potentially opposing effects, the network access fee effect and the rent extraction effect. As Choi and Kim mention in their article the ISP's relative incentive to invest in capacity in either regime is a priori ambiguous as we do not know the overall effect of the two effects.

We will later look at and discuss the model's predictions in chapter 7 as we use the model as a foundation to discuss any effects of the removal of net neutrality regulations in the U.S. that we find.

4.0 Data

To answer the question about net neutralities effect on investment I collected data about ISPs infrastructure investments for the period that we want to look at. When a company publishes that they have invested 10 million dollars in 2010 they can mean a lot of things. Investment numbers for a company might include what they spent on mergers and acquisitions as well as what they spent on maintaining, improving and/or expanding their fixed assets so it is important to look at first what measuring unit we will be using for the analysis and the arguments for why it was chosen.

4.1 Capital Expenditure

Economists have tried different approaches on how to measure infrastructure investment when it comes to the question of how best to measure the effect of net neutrality on companies' investments. While the debate over Net Neutrality is and has been highly politicized (especially in the US), several look to the annual Broadband Capital Expenditure measurements issued by USTelecom as a standard (Brogan 2019). The United States Telecom Association (USTelecom) is a trade body for telecommunications-related businesses based in the US and issues each year a report on telecommunications investments using capital expenditure as a measuring unit (Brogan 2016,2017, & 2019). These reports do not conduct any casual impact analysis– i.e., they do not draw any conclusions surrounding the impact of net neutrality on the industry but help establish capital expenditure as the standard for measuring industry investment.

Several researchers have followed this standard of measurement like Ford (2017, 2018), and Free Press (2017), but there have been arguments against using capital expenditure as a measurement as companies make investment plans several years in advance and it is thereby difficult to measure when the impact of any net neutrality regulation affect investment.

4.1.1 Capital Expenditure Incurred But Not Yet Paid

An alternative to capital expenditure is the measurement capital expenditure incurred but not yet paid as argued by Hooton's (2020). He argues that since capital expenditure can have been planned months if not years in advanced and therefore reflects poorly on any regulation changes as it is difficult to say when the firms are affected by the new regulation and place that point uniformly for all the firms in the sector. Instead, Hooton argues for the usage of

Capital Expenditure Incurred But Not yet Paid as the dependent variable for measuring telecommunications investment. Capital Expenditure Incurred But Not Yet Paid Hooton argues is a better measurement as it measures new investment obligations assumed in the current period rather than actualized with previous obligations captured by capital expenditures paid. According to Hooton this makes it possible to isolate ex post decisions and put out a more precise timeline, but Hooton has gotten pushback for the usage of this variable and an expression of concern was added to his paper by the editors for selection bias which has contributed to spurious results (Ford 2021).

Ford (2021) argues that the usage of the variable Capital Expenditure Incurred But Not Yet Paid is a faulty measurement that "measures postponed payments for prior capital expenditure decisions" and would therefore not provide as Hooton argues a more precise method for tracking reactionary investment but be liable for the same problem that Hooton argues capital expenditure have. It is also in the U.S. not required by firms to report the Capital Expenditure Incurred But Not Yet Paid and consequently the database that Hooton uses is not comprehensive and firms drift in and out of the sample with no devisable pattern or rhythm. Ford also points out that nearly half of Hooton's sample data show that capital spending is zero for that quarter or near to it and can therefore not be used as a good measurement of infrastructure spending.

Since Ford has shown that Capital Expenditure Incurred But Not Yet Paid is not a good dependent variable and previous economist including Ford has used capital expenditure as a good measurement of infrastructure investment and as we are interested in companies' investment in infrastructure will we only look at the part of investment that is capital expenditure.

4.2 Data Collection

For the data collection I have only looked at annual capital expenditure, though it would have been better and given a more accurate analysis to use quarterly data. This limitation was made due to time restraints when it proved to be too difficult to gather quarterly data for both the U.S. and Europe in a timely fashion without losing out on accuracy and so I decided to instead focus on what data I could gather within my time limit. Below you will see the collection prosses for both U.S. and Europe and view figures illustrating the data.

4.2.1 U.S. Capital Expenditure

I have gathered capital expenditure for telecommunications companies in U.S. by using USTelecom's annual Broadband Capital Expenditure reports. The report is made by gathering capital expenditure data for telecommunications, wireless telecommunications, and cable broadband providers, telecommunications resellers, and electric utilities (USTelecom 2021). The majority of the data comes from companies' annual financial statements, taking into account business segment reporting, accounting changes, mergers, and spin-offs. Because of this the data is thereby subject to the reporting practices of individual firms, but effort has been made in eliminating double counting, non-U.S. investment, and non-capital spending. But it is important to note that the data is an estimate of annual spending, and that the figures are rounded.

USTelecom do also consult additional sources for comparison like the United States Census Annual Capital Expenditure Survey, and New Paradigm Resources Group. And it is important to note that, especially since 2014, it has been necessary to adjust certain reported capital expenditure to ensure that the data series remains consistent over time and reflect actual change in the capital stock of the U.S. economy. This is because of large international mergers and accounting changes especially by AT&T's merger with DirectTV and Mexican wireless operations in 2015 and a change in the accounting treatment in 2014 and 2015 (Brogan 2016, 2019). The data spans the period from 2004 to 2020 and contains all three periods where the net neutrality regulations changed in the US, those being 2010 Open Internet Order and its removal in 2014, the 2015 Title II act and its removal in 2018 (Finley 2020).

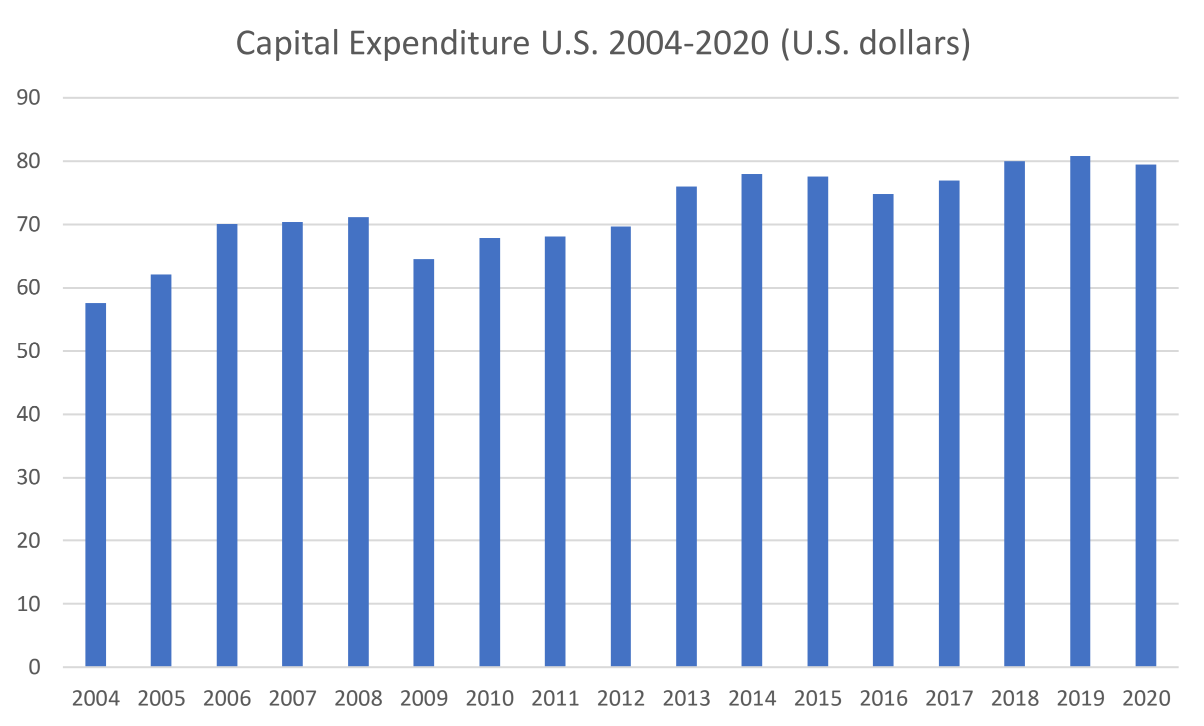

Figure 1:Capital Expenditure U.S. 2004-2020 (U.S. dollars) Source USTelecom. Figures are rounded

In Figure 1 we can see a clear increase in capital expenditure over time: from 2004 to 2020 spending on capital expenditure increased by 38.09%. Though we can also see several dips: in 2009, 2016, and 2020. Some of these dips may have been caused by financial insecurities like the 2008 financial crisis, which may be the reason that we see the dip in 2009, though its effects were felt a long time as capital expenditure would not reach its previous heights until 2013. One of the reasons for this might have been the Obama administrations implementation of the 2010 Open internet Order which may have been the reason that it took until 2013 for capital expenditure to reach its previous heights from 2008, but this is difficult say just from an overview of the data without doing a counterfactual analysis. We can also see that there is a downwards trend from 2015 but this reaches its lowest point by 2016 and is rising by 2017. This might have something to do with the Title II act of 2015, but it is once again difficult to say without analyzing the data further. In 2020 there seems to be a new dip as capital expenditure went down by 1.73% from 2019, this might have been influenced by the ongoing pandemic, but once more without further analysis it is impossible to say.

4.2.2 Europe Capital Expenditure

The data for capital expenditure for Europe was gathered by using the European Telecommunications Network Operators' Associations (ETNO) report "The State of Digital Communications" which is an economic report that is published annually and contains figures surrounding how competitive European broadband is compared to USA, Japan, and South Korea. Most of the data for capital expenditure in ETNO's report is a mixture between hard financial data collected directly from the members in ETNO and disaggregated capital expenditure. trends that Analysis Mason extrapolate from more limited data. To account for non-European investment, double counting, and non-capital spending, effort has been made in eliminating them. ETNO covers every European country except Russia, Ukraine, Belarus, Iceland, and Turkey, so Europe will in this thesis mean every European country except those mentioned above.

For Europe the data has been collected using ETNO's "The State of Digital Communications" reports of 2022, 2021, 2018, and 2016. And by using ETNO's annual economic report for the years spanning 2010 to 2004.

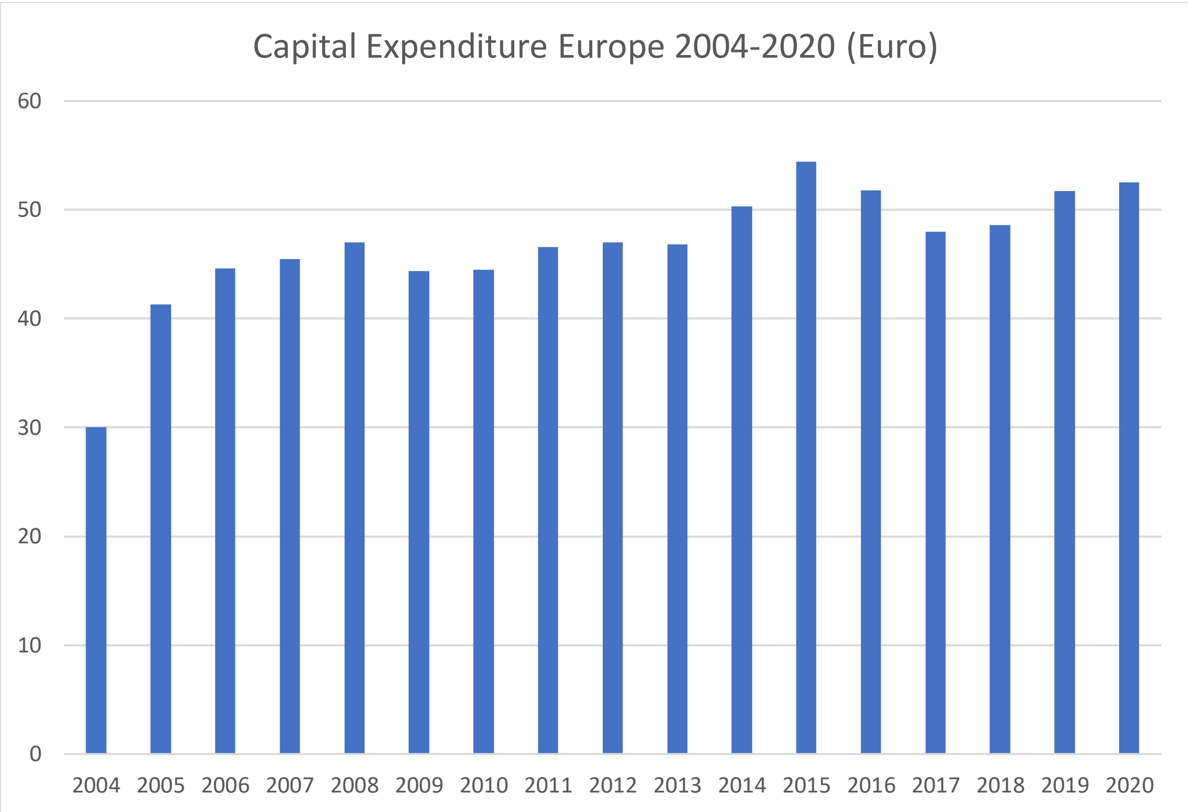

Figure 2:Capital Expenditure Europe 2004-2020 (Euro). Source Analysys Mason. Figures are rounded

As with the U.S., in Figure 2 we can see a clear increase over time in capital expenditure in Europe. From 2004 to 2020 capital expenditure has risen by 75%, a lot steeper than in the U.S., but this might be because of Europe's lower spending in 2004 that skews results. If we look from the period 2005 to 2020, investments have increased by 27.12% which is less than the U.S.

Europe also differs from the U.S. by the fact that from 2015 till 2020 investment fell by 3.49%, but since reaching its lowest point in 2017 investment in Europe has been on a rise with increases in capital expenditure spending. From 2017 till 2020 capital expenditure in Europe rose by 9.48%.

When comparing capital expenditure investment between the U.S. and Europe there are a few similarities like the downturns in investment in 2009, but Europe had a quicker rise back to its previous investment levels while it took until 2013 for the U.S. to do the same. Both Europe and the U.S. show a fall in investment levels in 2016, but while the U.S. reached its lowest point in 2016 it took until 2017 for Europe to do the same. Europe has lower capital expenditure than the U.S. a reason for this might be that there is higher competition as Europe is characterized by a large number of smaller firms with limited footprints compared to the U.S. with a much denser concentration of power where large firms hold most of the consumers. In Europe there are 47 mobile operators with over 500 000 subscribers while USA has 7 (ETNO 2020). Europeans also spend less on average on fixed broadband than their American counterparts, the average revenue per user in Europe is 21.5 euros while in the U.S. the average is 49.1 euros (ETNO 2022).

4.3 Additional data

4.3.1 Europe Revenue

While not a part of the analysis it is interesting to look at the revenue data for telecommunications industry in Europe and the U.S. On Figures 3 and 4 you can see graphed out telecommunication firms' revenue in the period 2005-2021. For Europe I once again used ETNO's State of Digital Communications reports to collect the revenue data. I did this to make sure that I only collected data for Europe and did not include revenue gained in Asia, America or Africa as several large European telecommunications companies have made their way into those markets in the last decade like Telenor's interests and investments in Asia (Telenor 2021).

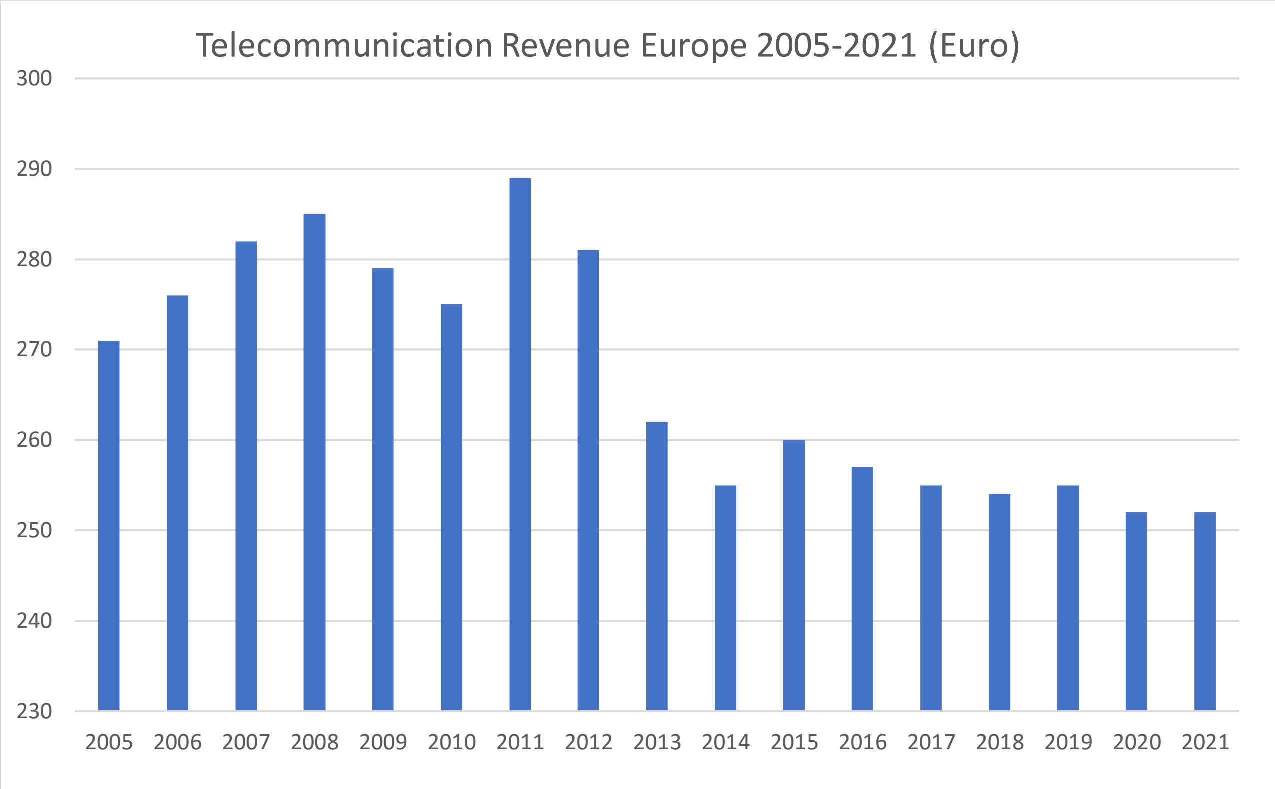

Figure 3: Telecommunications Revenue Europe 2005-2021 (Euro). Source Analysys Mason. Figures are rounded.

We can clearly see that revenue in Europe is on a downward curve with revenue falling from its highest point 289 billion euro in 2011 to 252 billion euro in 2021 this is a fall of 12.8%. The reason for this might be as mentioned previously of tough competition among the providers and lower average revenue per users in Europe than in the U.S.

4.3.2 USA Revenue

Below you can see revenue for telecommunication firms in the U.S. for the 2004-2020 period, the revenue data was collected from Statista (2022). The data was gathered by Thomas Alsop through information filed with the Commission in FCC forms 499-A and 499-Q which firms in the telecommunication sector are required to report if they have a direct universal service obligation[2] in the U.S. The revenue that is reported in by the firms have to be separated into revenue earned within the U.S. and its territories, and what is earned outside, meaning that the graph only shows what the sector has generated inside of the U.S. It is important to note that

[2]A filer does not have to file for a given calendar year if the revenue reported is such that the calculated annual contribution to the federal Universal Service Fund is less than $10,000 (FCC 2021).

to an extent certain industry revenues aren't subjected to contributions and therefore may not have been fully captured in the graph.

As the graph shows U.S. has seen a similar downward trend in revenue as Europe, with a fall from its highest point of almost 300 billion US dollars in 2007 to 133 billion in 2020.

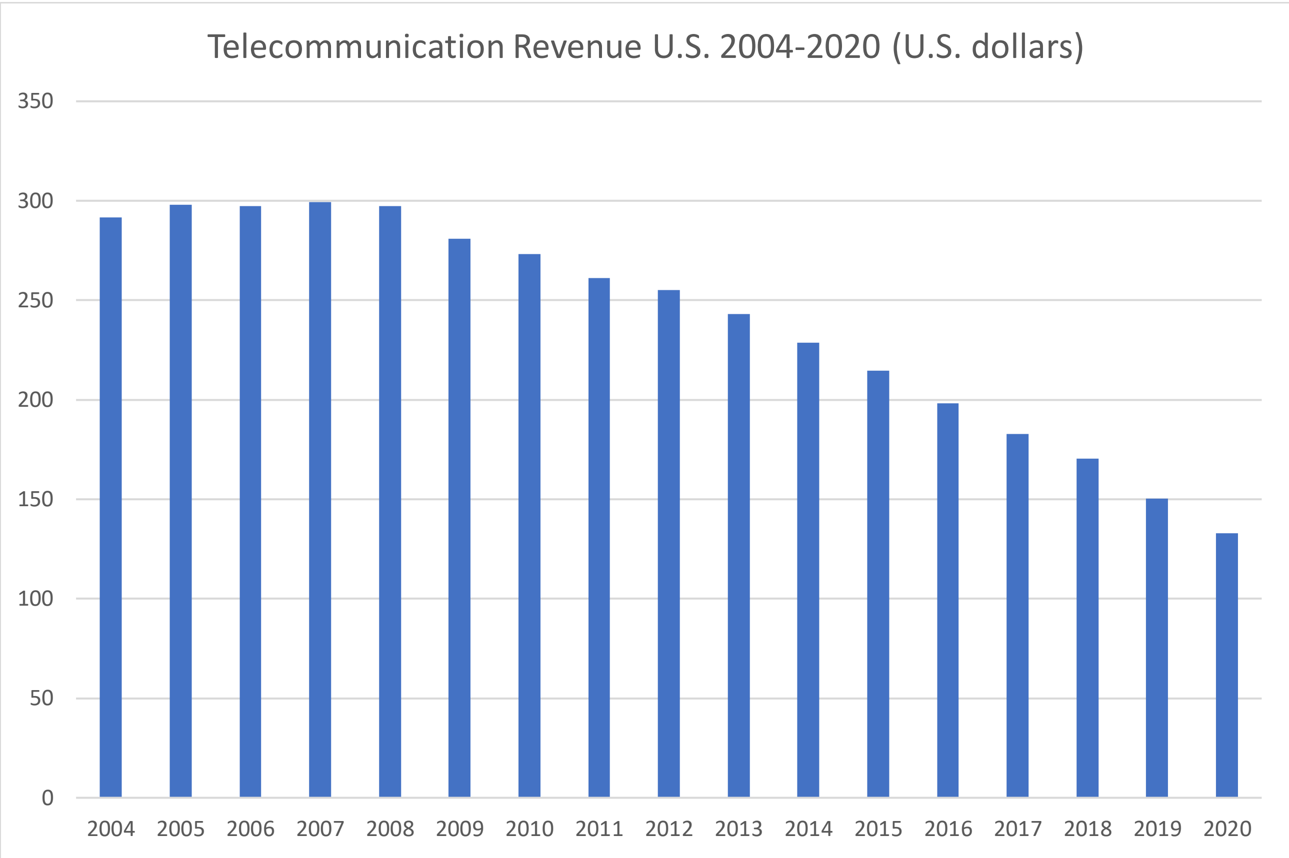

Figure 4: Telecommunication Revenue U.S. 2004-2020 (U.S. dollars). Sources Statista. Figures are rounded.

4.4 Counterfactual

Both Ford (2017, 2018) and Hooton (2017) used different solutions in making their control groups, but both faced criticism for their choices. Ford criticized Hooton's 2017 analysis for his usage of only a single control selected. Hooton used the average investment data from an unspecified number of OECD nations which did not take into account that most OECD countries were discussing implementing some form of Net Neutrality regulation which would affect any investment results. While Hooton recognized the problem and removed all the countries that already had net neutrality regulation or where in discussion about it, no list was given of countries included in the sample nor countries that were removed (Ford 2019).

While Hooton (2020) criticized Ford (2017) for using a synthetic control group made from non-telecommunication sectors that fails to account f or spillovers from the regulation into other sectors isolating policy jurisdictional scope. Hooton (2020) would in the same paper use a similar control group, moving away from his previous choice.

For this analysis I have decided to use the telecommunications sector in Europe's capital expenditure as the counterfactual control group for this difference-in-difference analysis. Both Europe and the U.S. have similar timelines when it comes to enacting net neutrality regulation. In Europe, the EU passed a uniform provision on net neutrality in 2015, though it wasn't until a year later that it went into effect (Rundfunk und Telekom Regulirungs-GMBH 2021)

.

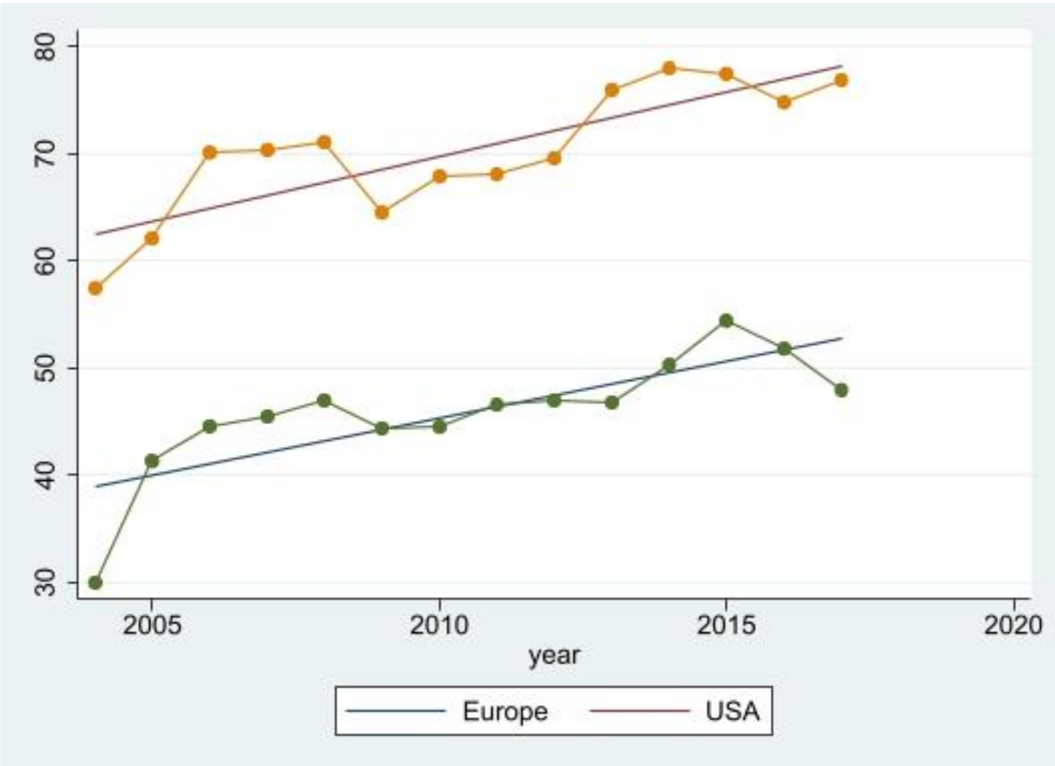

Figure 5: Capital Expenditure for Europe and USA with linear trend lines. 2004-2020. Figures are rounded and in US dollars.

Similarly, the U.S. passed their Title II Act in 2015 when they moved ISPs to being classified as common carriers, this went into effect the same year (FCC 2015).
Europe has kept their net neutrality regulations while the U.S. removed theirs, making it a comparison between one group with the regulation and one without. It is still important to note that the U.S. has several times passed net neutrality regulations, but that these have been quickly struck down when compared to the Title II Act and been seen as weaker regulations

with less power (FCC 2015). If we compare the two groups capital expenditure spending visually with a trend line and limit the data to before net neutrality was removed in the United States, they seem to visually follow a parallel trend. I will later in this thesis test to see if this assumption holds, by using a placebo test.

5.0 Difference-in-Difference Model

In many fields, such as medicine and psychology, casual effects are commonly estimated using experiments. For example, before being approved new drugs must go through rigorous testing to see if they are safe to use and also to see if it can prove causal results on treatment. This is done through the usage of experimental trials where some patients are randomly selected to receive the new drug and others are given a harmless and ineffective substitute (a placebo). Any new drug is only approved for use if the manufacture can prove with randomized controlled experiments convincing statistical evidence that the drug is safe to use and effective (Stock & Watson 2020, p.474)

But when testing the effect of the removal of Net Neutrality on Internet service providers capital expenditure, it isn't possible to execute a traditional randomized controlled experiment in the same manner. To evaluate the impact, you would preferably want to compare the same population with and without the regulation as the best way to measure the effect of the regulation. If you could have two identical individuals where everything is the same except one of them has been exposed to a treatment and the other hasn't it would be easy to compare the two to find out the effect of the treatment. This is because the two individuals would have continued being identical if it hadn't been for the treatment. But in cases like this where the entirety of the population that you want to study is exposed the best thing to do is find a control group that can serve as the counterfactual and is as similar to the treatment group as possible.

We let $\bar{Y}$ represent the average capital expenditure of Internet service providers for a given period and let T stand for the treated group and C stand for the control group.
If we compare the treatment group before, $\bar{Y}_0^T$ and after the removal of the regulation, $\bar{Y}_1^T$,we will get an estimator that is based on the difference in outcome from before and after treatment in the treatment group alone:

$$\hat{\delta}_1 = \bar{Y}_1^T - \bar{Y}_0^T \tag{15}$$

But simple comparison of before and after does not account for time-trends that might exist in the outcome and that might thereby affect the estimator by making us confound the time trend as being part of effect of removing the regulation.

Instead of only comparing the difference in capital expenditure in the treatment group before and after the regulation was removed, we could compare the average difference in outcome after the regulation was removed between the control and the treatment group:

$$\delta_2 = \bar{Y}_1^T - \bar{Y}_1^C \tag{16}$$

Similar to before, while this estimator does take into account time trends, it doesn't take into account the permanent differences between the two groups that already exist prior to the regulation and that will be confounded as being part of the effect of removing the regulation.

To find the actual effect that the removal of the regulation has on Internet service providers a difference in difference estimator is used.

5.1 Difference in Difference estimator

This estimator takes the difference in the average outcome before and after treatment for the treatment group and subtracts from it the difference in the average outcome before and after treatment for the control group, controlling thereby for both time trends and prior permanent differences between the two groups:

$$\hat{\delta}_{DD} = \bar{Y}_1^T - \bar{Y}_0^T - (\bar{Y}_1^C - \bar{Y}_0^C) \tag{17}$$

To be able to say that the estimator is unbiased there are several assumptions that must be fulfilled. These assumptions are:

1. The model's outcome is correctly specified.
2. The error term is on average zero.
3. The error term is uncorrelated with the other variables in the equation.
4. There exist a parallel trend before treatment.

The parallel trend assumption is the assumption that in the absence of treatment the difference between the two groups is constant over time. It is considered the most critical of the assumptions and the hardest to satisfy. If the model does not fulfill this then we have no guarantee that the difference-in-difference estimator is unbiased assumption, but the assumption is difficult to check (Angrist & Pischke 2015, p.178-188)

5.2 Model

The applied model is therefore defined as:

$$Y_{it} = \alpha + \beta(Treatmeant_{it}) + \gamma(Location_{it}) + \delta(Treatmeant_{it} * \ Location_{it}) + X_{it} + \varepsilon_{it} \tag{18}$$

Where Y_{it} is the observed level of outcome at time t and firm i. $Treatmeant_{it}$ is a dummy variable for time that represents if it is post-intervention. In this case it represents the difference in the data before and after 2018 for both groups. $Location_{it}$ is a dummy variable that marks if the data is for the treated group or the control group and shows the difference between the two groups. $Treatmeant_{it} * \ Location_{it}$ is the interaction variable, where δ is the difference-in-difference estimator that gives us an estimate of the impact that the removal of net neutrality had on investments in the telecommunications industry in the U.S. X_{it} is a vector for the variables for the two groups at time t in this case annual GDP, and population density, while ε is the error term (Angrist & Pischke 2015, p.187-188).

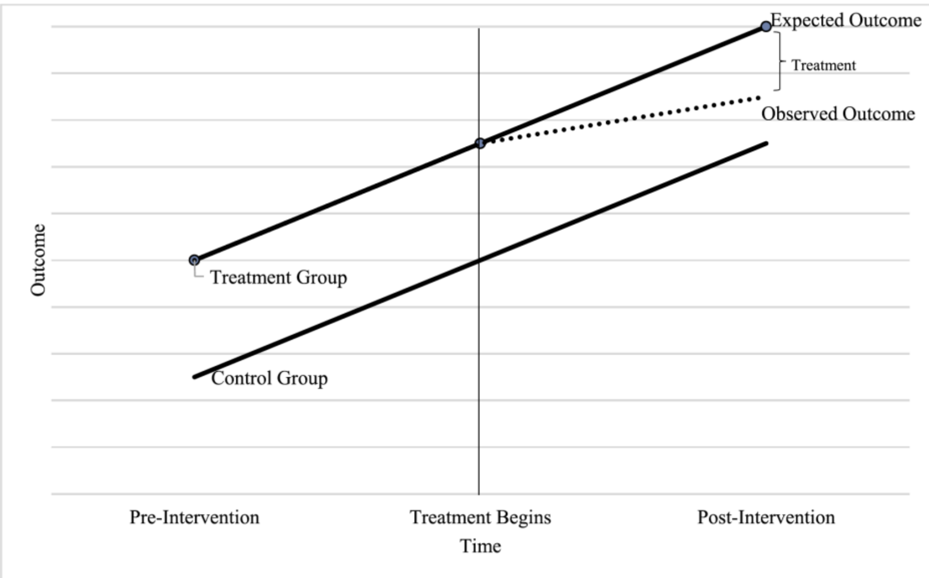

Figure 6: Difference-in-difference illustrated. Sourced from Hooton (2020)

Treatment date is also something economist have disagreed on when it comes to at what time companies would react to the regulation or in this case to the removal of the regulation. Companies often plan investments long before they implement them so it is hard to say what the exact time firms reacted to the removal of the regulation, the telecommunication sector might have had an idea that the FCC was planning on removing the regulation since 2016 as Trump was voted in as President, but the actual removal did not happen until June of 2018 (FCC 2018). Companies might have prepared themselves for this, but it is difficult if not impossible to pinpoint the exact time that the industry reacted. Because of this I have decided to act similar to Singer (2017), Hooton (2020) and Kovac (2017), that all used 2015 as the treatment date as it is when the regulations were put into effect and use 2018 as the treatment date for this thesis. 2018 was the year the regulations were removed, but it was already in discussion in 2017, meaning that companies might have started preparing for a lessening in regulations (Finley 2020). It is difficult to test the casual impact of a single policy change on an industry's decision-making and the difficulties in setting treatment date makes this even harder (Hooton 2020). The precedence is there for arguing that as the year net neutrality was put into effect can function as the treatment date for testing the casual impact of net neutrality regulations, the same can be said for the year of its removal.

Table 1: Summary of data variables for period 2004-2020

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Year	34	2012	4.973	2004	2020
Capital Ex.	34	59.40	14.18	30	80.80
GDP	34	16.11	2.343	12.06	21.43
Population density	34	66,167	32,458	31.96	99,529

Table 1 shows a summary of the data variables, including averages, and the minimum and maximums points of the data set. To control for outside forces that might influence investment in the years that we are looking at it is important to add control variables. It is important to control for outside forces that we believe would affect ISP's investment incentives. In this thesis I have decided to only focus on two of these variables: GDP, and population density. GDP for this thesis covers the annual GDP for Europe and USA in the period 2004-2020. This is to control for the overall economic performances of these two groups as companies will not want to invest in times of economic uncertainty and it therefore is a key determinant of a company's financial decisions. Population density is added as a control variable as it explains with what ease companies can invest. In high density areas like large cities the cost of infrastructure can be spread out among a higher number of customers than it can in a rural area. A survey done by Pew Research Center found that in the U.S. residents living in rural areas are less likely to report having home broadband and less likely to own a smartphone, tablet computer or a traditional computer (Vogels 2021). In Figure 7 we can see the difference in annual GDP for Europe and USA in the period 2004-2020.

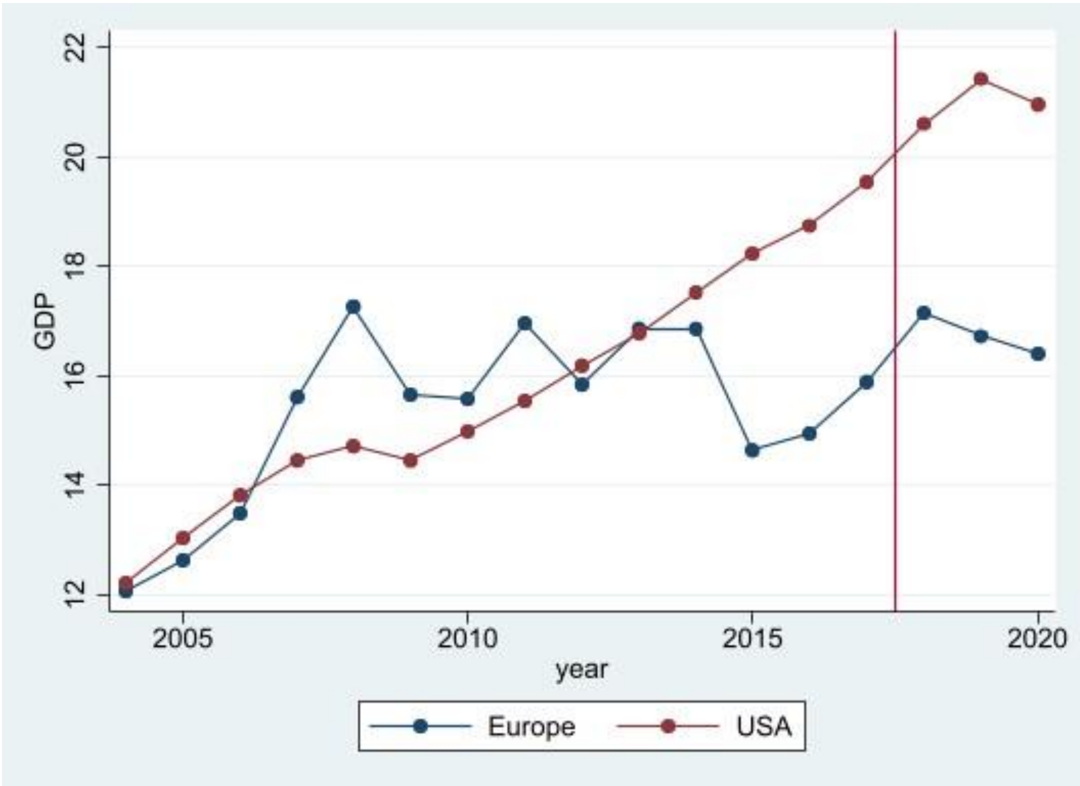

Figure 7: GDP for Europe and USA. 2004-2020. Figures are rounded. Source World Bank

We can see clearly that USA has a much steeper growth in the last 5 years when compared to Europe's much flatter GDP development for the same period. It is easy to see that while the United States might have suffered a small dip in GDP in 2009 following the 2007-2009 global financial crisis, it quickly went back to previous levels and have since maintained a steady growth. Though we can see that GDP fell in 2020 for both USA and Europe, this was most likely caused by the ongoing Covid-19 pandemic that shut down large parts of the world economy. Europe has compared to the U.S. had a much flatter development in their GDP in the last 18 years. After the 2007-2009 global financial crisis, Europe experienced a much slower recovery than the U.S. with several dips in annual GDP. They also did not achieve the same level of GDP that they had in 2007 until 2018.

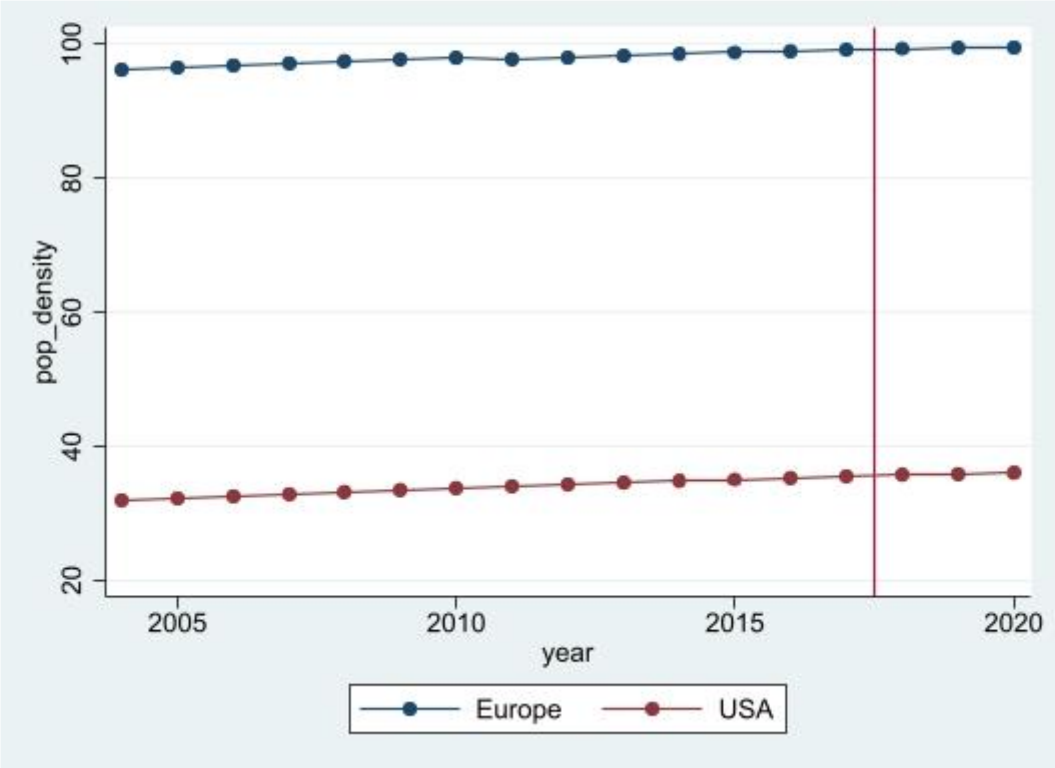

Figure 8: Population density for Europe and USA. Figures are rounded. Source World Bank

Figure 8 shows the difference in population density between Europe and USA. Europe has a much higher population density than the United States, but we can see that the population density in U.S. has steadily increased in the last 18 years.

Both control variables were collected using data from the World Bank and includes figures from USA, EU, Norway, and Switzerland.

5.3 Limitations

It is important before we go on to mention the limitations of this analysis. One of the biggest being the sample size at only 17 data points on the dependent variable for each group and the limited time series after the regulation was removed.

The data only covers annual capital expenditure instead of quarterly this means that the sample seems small even if it is comprised of a large number of firms for each data point, but as it is lacking the quarterly results. This means that the data set might be missing important nuances, and this makes it harder to pinpoint a more accurate treatment point. For example, the removal of net neutrality regulations in the US happened in June of 2018, putting the treatment point instead of as the entire year of 2018 might mean that we over- or underestimate the effect that the removal of net neutrality regulation has on investment incentives for Internet service providers.

6.0 Results

6.1 Primary findings

Below you can see the findings for the difference in difference analysis on the impact of the removal of net neutrality regulation. If the removal of net neutrality regulation in the US changed broadband investment, then I would expect to find significant results, either positive i.e. Internet service providers increase their capital expenditure or negative i.e. Internet service providers lower their capital expenditure. To check this the variable, we are interested in is labeled DiD and is the difference-in-difference estimator in Table 2. Table 2 shows that the removal of net neutrality regulation caused an increase in investment spending, but it isn't statistically significant. As Table 2 shows this increase is very weak as the removal of net neutrality regulation is shown to only bring an increase in capital expenditure spending of 7 million US dollars a year, which is small as it is only a percentage of telecommunications investment (0.01% of the mean) in a year. The increase is also not statistically significant so we cannot say if there exist a causal impact or not.

To account for outside effects that might affect capital expenditure in 2018 besides the removal of the Net Neutrality regulation we add the control variables for GDP and population density. This is to account for outside influences that might affect investment incentives as mentioned in the previous chapter. When adding the control variable for GDP, we can see in regression (2) that we now have a negative result or a decrease in capital expenditure by 0.067 or 67 million US dollars a year. This decrease is statistically significant unlike what we saw when we only ran the regression without control variables indicating that there might be a casual effect on capital expenditure caused by the removal of the Net Neutrality regulations. While the results are statistically significant, they are only so at the 10% level which is quite low with a p-value of 0.081. Even though the regression is showing a larger effect than before, the removal of the net neutrality only seems to lower the capital expenditure spending by 0.11% from the average year.

Table 2: Difference-in-difference regression

	(1)	(2)	(3)	(4)
VARIABLES	CapEx	CapEx	CapEx	CapEx
Treatment Dummy	5.376***	2.574	3.905**	2.870*
	(1.861)	(1.710)	(1.740)	(1.499)
Location Dummy	0.357***	0.339***	0.976***	0.649**
	(0.026)	(0.018)	(0.059)	(0.260)
DiD	0.007	-0.067*	-0.063**	-0.075**
	(0.029)	(0.037)	(0.025)	(0.034)
GDP	45.555***	1.750***		1.112
	(1.547)	(0.421)		(0.99)
Population density			0.692***	0.339
			(0.058)	(0.297)
Constant		19.032**	-21.812***	-4.354
		(7.195)	(5.446)	(13.361)
Observations	34	34	34	34
R-squared	0.906	0.949	0.946	0.953

Robust standard errors in parentheses

* p<.1; ** p<.05; *** p<.01

In regression (3) we can see the results of adding the control variable of the population density which shows a decrease in capital expenditure spending by 0.063 or 63 million US dollars a year (0.11% of the mean). This result is similar to what we found when we controlled for GDP in regression (2), but the significance level is higher at 5% with a p-value of 0.017, much lower than in regression (1).

In regression (4) we can see the regression with both control variables, here we can see that we get a higher effect than the two previous regressions showed with a decrease in 0.075 or 75 million US dollars (0.13% of mean) in capital expenditure following the removal of the Net Neutrality regulations, this result is statistically significant at the 5% level, but the p-value is 0.031 which is higher than what it was in regression (3).
We can see with all the statistically significant results that we have gathered that the removal of net neutrality regulations appears to have caused a decrease in capital expenditure spending, though this appears to be a weak effect at only 0.13% of the mean.

In Figure 9 we can see the capital expenditure spending over time for the period 2004-2020 with a line to mark when the regulations were removed in 2018. Both Internet service providers in Europe and USA increased their capital expenditure spending from 2004 to 2020.

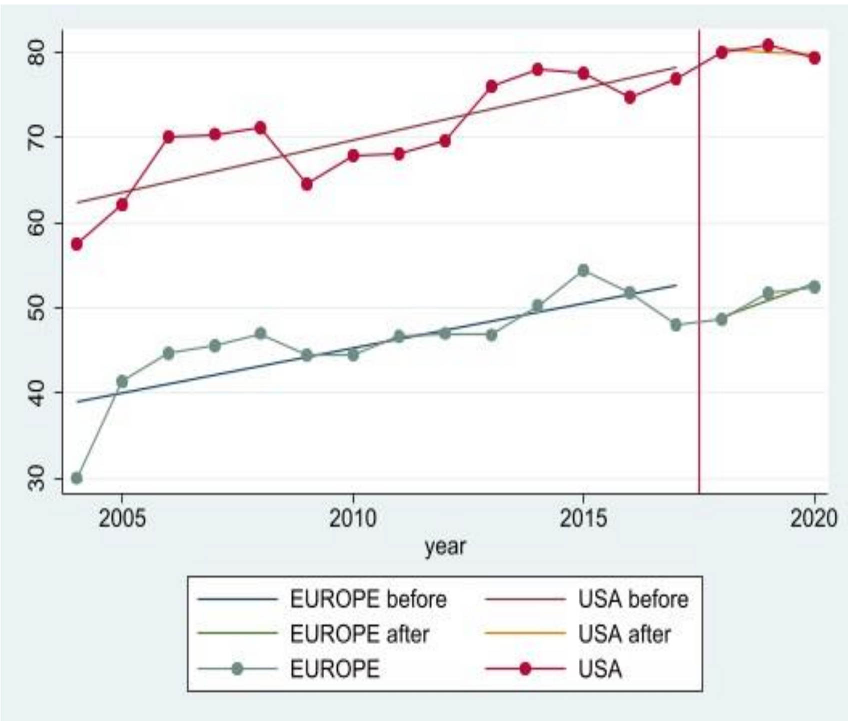

Figure 9: Capital expenditure: Europe and USA with linear trend lines

Here we can see and compare the two groups trend line before and after treatment. Both have

Here we can see that visually the two groups seem to follow a parallel trend with each other. Both show a trend of steadily increasing capital expenditure in the period 2004-2017. But after the net neutrality regulations were removed in the U.S., we see a decrease in spending in the U.S. while in Europe capital expenditure continues to increase.

If we add instead a non-linear trend line as we have done in Figure 10, we can see that while capital expenditure in Europe and USA seems to follow a similar trend, capital expenditure in the USA looks to increase at a steeper rate than in Europe.

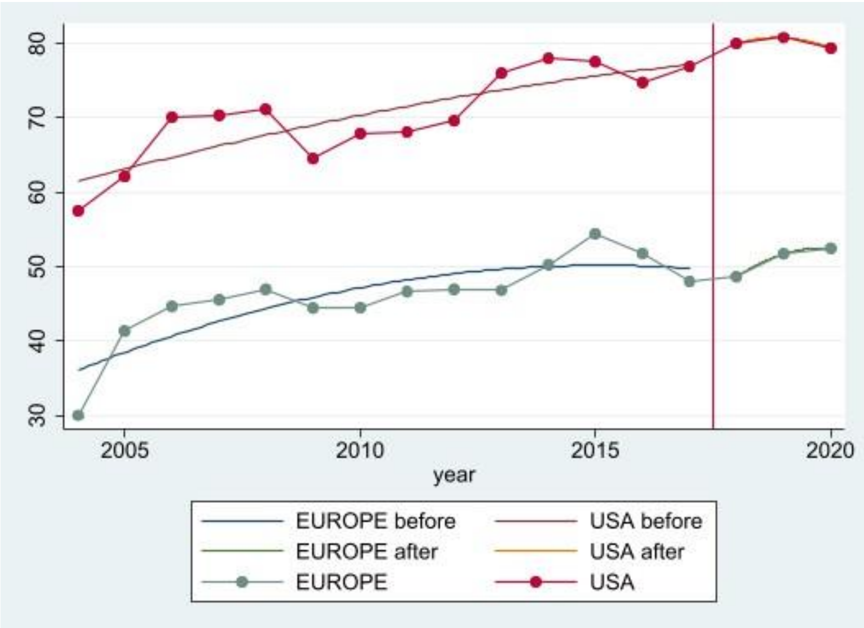

Figure 10: Capital Expenditure: Europe and USA with non-linear trend lines

This can mean that the difference-in-difference assumption of equal trends might be broken. To find out if the results that we have found in the previous regressions are not the results of other variables than what I want to examine, and to find out if the assumption of equal trends between the treatment and control group holds, we will later perform a placebo test.

6.2 Placebo

The placebo test is done to check if the assumption that was made earlier about the two groups sharing parallel trends is correct or not. If the two groups do not share a parallel trend, then they cannot be compared with each other as they differ too much.

This is done by removing the time period after the treatment period, in this case every year after 2017. Then we pick a fake treatment period in the pre-treatment data, in this case 2014 was randomly picked. I have also reversed the groups so that Europe is now the treatment group instead of USA. Below you can see the summary of the variables in the limited data set. We now have 28 data point, 14 for each group and a lower average in capital expenditure than before.

Table 3: Summary of data variables for 2004-2017

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Year	28.000	2010.5	4.105	2004	2017
CapEx	28.000	58.096	13.721	30.000	78.000
GDP	28.000	15.521	1.903	12.065	19.543
Population density	28.000	65.845	32.597	31.959	99.188
Europe	28.000	0.500	0.509	0.000	1.000

We now execute the same analysis as before, but with the fake treatment time and with limiting the data set to the time period 2004-2017. By running the same regression analysis in STATA, we get the regression outputs as seen below. Where regression (5) is without control variables while regressions (6) and (7) include one of the control variables with (6) including GDP as a control variable and (7) including population density. While (8) includes both control variables.

In the placebo regression without control variables (5) the difference-in-difference estimator is not statistically significant, but when we add the control variable for GDP (6) we find that the placebo treatment had the effect of an increase in investments that is significant at the 5% level. While if we add the control variable for population density (7) we find that the treatment resulted in a decrease in investment that is significant at the 1% level.

When we add both control variables there is no longer a statistically significant effect, meaning that we can assume that the parallel trend assumption holds for this analysis. While it can look as though the parallel trend assumption does not hold when only accounting for one of the control variables, when we add both we see that the estimator is no longer significant.

	(5)	(6)	(7)	(8)
VARIABLES	CapEx	CapEx	CapEx	CapEx
Treatment dummy	9.734***	-1.882	11.087***	3.533
	(1.963)	(4.016)	(1.963)	(3.186)
Location Dummy	-0.510***	-0.567***	1.001***	0.613***
	(0.049)	(0.044)	(0.108)	(0.215)
DiD	0.014	0.237**	-0.188***	-0.002
	(0.063)	(0.114)	(0.04)	(0.087)
GDP		2.861***		1.782**
		(0.967)		(0.721)
Population density			-1.059***	-0.809***
			(0.866)	(0.121)
Constant	66.908***	25.490*	102.969***	68.655***
	(1.844)	(14.461)	(3.477)	(15.526)
Observations	28	28	28	28
R-squared	0.832	0.913	0.939	0.963

Table 4: Difference-in-difference regression analysis for Placebo

Robust standard errors in parentheses

* p<.1; ** p<.05; *** p<.01

7.0 Discussion

There has been done few empirical analyses on the effect of net neutrality regulation on investment incentives and the findings they present are disputed. When the FCC in 2018 decided to remove Title II regulation on Internet service providers under the Restoring Internet Freedom Order they concluded that overturning the 2015 Open Internet Order would likely increase Internet service provider investment and output (FCC 2018 p.58).
I have yet to find any studies to prove that there has been an effect on investments after the regulation was removed, as the studies that I have looked at have all focused on the effect that the implementation had on Internet service providers investment, and here the conclusions are varied.

Some like Kovac (2017) and Ford (2017) concluded that net neutrality regulations affected investments negatively, but Kovac (2017) used a simple before and after difference estimator. This simple estimator does not take into account time trends and is considered a poor estimate of the effects of any regulation. Ford (2017) uses a counterfactual analysis based on a control group and applied a difference-in-difference estimator to quantify the effects. He found a large negative investment effect from the implementation of the net neutrality regulation, but Ford has been criticized for using 2010 as the treatment date for the implementation of net neutrality to measure the effect that the 2015 implementation had (Hooton 2020).

Others argue that the implementation had no effect on investment, like Hooton (2020) who also used a counterfactual analysis based on a control group and applied a difference-in-difference estimator. He found no statistically significant effect of the implementation of net neutrality but has been heavily criticized for his use of Capital Expenditure Incurred But Not Yet Paid as his dependent variable (Ford 2021).

The results I have found in this thesis does not look at the effect of the implementation of net neutrality regulations rather the removal, so it is difficult to make comparisons between the results from this thesis and previous studies. It can be argued that when Ford (2017) shows a clear decline in capital expenditure spending after the implementation of net neutrality regulation in the U.S. market that you would see an opposite effect after its removal. What the result of this thesis instead shows is a decline in investments. This decline is small and only 0.13% lower than from an average year, but still opposes the theory that the FCC (2018) and

Ford (2017) argued for that the removal of net neutrality regulations would lead to increased investment spending from the ISPs. Though it is important to point out that this thesis data foundation is not as strong as Ford (2017) was as it only contains annual results and not quarterly. Because of this, we lose some nuances and might over- or underestimate the effect.

To explain why the results show a decrease in investment, we can look at the model presented earlier in this thesis by Choi and Kim (2010) and what their findings say about our data. Their model tries to find out if there is a difference in an ISPs willingness to increase capacity under the two regimes. They argue that an ISPs choice to invest depends upon two effects: the network access fee effect and the rent extraction effect.

Where the network access fee effect is the effect that an increase in network capacity has on the end user's willingness to pay the ISPs, as an increase in capacity levels would decrease transportation cost for the consumer who subscribes to the content provider with priority lessening its value for the end user. And an increase in capacity would only marginally affect the delivery speed of content from content providers with priority when compared to a change in delivery speed for users under the neutral network. But any capacity increase in a discriminatory network also affects the position of the marginal user who is indifferent between the two competing content providers.

While the rent extraction effect captures the effect that an increase in capacity level would weaken the ISP's incentives to invest in capacity under a discriminatory network since the merit from priority access and through that the value that it holds for content providers are relatively small and would decrease as the congestion problem becomes less severe.
For an ISP to increase capacity it needs to have a profit incentive, meaning that it will earn more if it increases capacity than if it doesn't. An increase in capacity affects how much the ISP can charge the end users and how much it can charge the CPs for priority.

To understand the conditions an ISP would want to invest in, Choi and Kim rearrange the terms in equation (14) to get:

(19)

$$\frac{d\tilde{\pi}_m}{d\mu} - \frac{d\pi_m}{d\mu} = \left[\frac{1}{(\mu - \tilde{x}\lambda)^2} - \frac{1}{(\mu - \lambda)^2}\right]$$

direct effects of capacity expansion

with market shares fixed (-)

$$+ \left[2(m_2 + \theta\Delta_m) - \frac{1}{(\mu - \tilde{x}\lambda)^2} - \frac{t}{\lambda}\right]\lambda\frac{d\tilde{x}}{d\mu}$$

indirect effect of capacity expansion
through changes in market shares (?).

This splits the two effects into a direct effect of capacity expansion where you have fixed market shares, and an indirect effect of capacity expansion where the market shares can change.

The terms in the first square brackets shows the direct effect of any capacity expansion on the marginal consumer's willingness to pay when the market shares are fixed between the two CPs. The difference in the ISP's profits between the two is always negative as $\frac{1}{(\mu-\tilde{x}\lambda)^2} < \frac{1}{(\mu-\lambda)^2}$, as the effect of increasing capacity is lower under a discriminatory network than under a neutral one. This is because when the market shares are fixed between the two content providers, an increase in capacity will only marginally affect the delivery speed for consumers who subscribe to the content provider with first priority since as capacity increases, they are already receiving their content quickly. But this will have a higher effect in the neutral system as any capacity increase affect the delivery speed symmetrically between the two content providers.

The remaining terms represent the effects of capacity expansion through the induced changes in the CPs' market shares. The second term in the square brackets show the effects that the margins of the CPs and the ISP's bargaining power have on investment incentives, this effect might be positive, or negative. But a sufficient condition for the ISP to have a higher incentive to invest in capacity in a discriminatory regime would be that this term is negative (≤ 0).

If the difference in the margins of the CPs are high and ISP's bargaining power increases, then it becomes more likely that the ISP will have more incentives to invest in a neutral network as the rent extraction motives are stronger under such a situation than under a discriminatory network.

As mentioned earlier, in chapter 3, capacity expansions affect the marginal consumer under the discriminatory network negatively. An increase in capacity levels means that as the wait time difference between the two content providers decreases it make it easier for the indifferent marginal consumer to switch between the two CPs.

But the ISP might have a higher incentive to invest in capacity under net neutrality if the marginal consumer is not affected by a change in capacity levels, or $\frac{d\tilde{x}}{d\mu}$ is close to zero. This happens when the content from the two content providers is differentiated enough so that the consumer will not want to switch between them even if the capacity level, and through that the delivery speed increases. In this scenario, the direct effect dominates, and the ISP will have higher incentives to invest under net neutrality.

But what does this say about the results that we have found? The results of our analysis show a reduction in capital expenditure after the removal of net neutrality regulations in the U.S. that goes against what the FCC (2018 p.58) predicted would happen. But Choi and Kim (2010) show that this reduction might not have been that unpredictable, as they argue that ISPs might not have a higher incentive to invest under a discriminatory network than they have under a neutral one.

Since we know the direct effect of an increase in capacity level when the market shares are fixed, we will now look at the second term in the square brackets as we are interested in seeing how the incentives shift when it comes to under which regime they would have a higher incentive to invest under. The fall in investment after the net neutrality regulations were removed can be explained through this equation as a combination of either high bargaining power among the ISPs, high margins by the CPs, low product differentiation between the CPs, low wait time on the content provider with first priority, change in content request rate or some combination of them. While it is hard to say anything about the exact strength of each variable, we will go into how some of them affect investment and how realistic the assumption of their strength is for the period that we are interested in.

In the equation, high bargaining power for the ISPs will lower investment incentives under the discriminatory network as the rent extraction effect is stronger under the neutral network.

It is not unreasonable to think that in the United States ISPs hold a high bargaining power over CPs as the market is divided among a few large ISPs that dominate and caused a fall in investments under the discriminatory regime (O'Dea 2022). But it is difficult to say how much this affects what ISPs can charge from the CPs as we do not have access to the prices that the ISPs charge the CPs for first priority nor how high the bargaining power actually is. If we look at the annual revenue that the sector generates as seen in Figure 4 as a representation of market power, it does not give us a clearer picture. Figure 4 does not show us an increase in revenue as you would expect to see after the regulations were removed but instead, we can see a continuation of the steady decline in annual revenue that has been ongoing since 2007. We do not know the breakdown of the income in this revenue and can therefore not know how much the additional revenue that it makes in fees from content providers - if any - contributes to the annual revenue. It is therefore difficult to say how strong the ISP's bargaining power is as even though few firms dominate the market it does not seems to be reflected in the overall profitability of the sector.

It is difficult to say how unrealistic low product differentiation is between content providers online in the United States in today's market. There have been arguments made that content online have started to look more similar in the last decade with websites and people's user experience becoming more universal as people become used to moving in online spaces and have expectations on how these spaces are formed (Goree 2020). How easy it is to move from using one content providers website compared to another varies as several variables play an effect in the user's experience, but we can assume that moving from one website to another if they both offer a similar product is quite easy. This is of course a large oversimplification, but as we do not have an overview of transportation cost online it is not an unreasonable assumption to make.

An important part of the equation is the content request rate as it affects several parts of the equation, and it is not as easy to see how change in it affect the ISP's incentive to invest. In the U.S. there has been a steady rise in the number of American adults who use the Internet over the last 20 years. Pew Research Center (2021), which track Americans' internet usage, could report that in 2020 93% of American adults use the Internet, compared to 89% in 2018 and 86% in 2015, marking a steady increase. The Covid-19 pandemic also affected internet usage as ISPs could report heavier broadband usage in the first quarter of 2020 than predicted with a usage spike of 47% compared to previous years (Robuck 2020). So how will this steady increase in Internet usage affect the investment incentives?

To test this out we first need to add the equation for the marginal consumer, this equation is helpfully made available to us in Choi and Kim's (2010) paper as:

$$\tilde{x} = \frac{1}{4\lambda}\left(2\mu + \lambda - \sqrt{(2\mu + \lambda)^2 - \frac{8\lambda^2}{t(\mu - \lambda)}}\right)$$

(20)

We can now add the equation we get in the marginal consumer (20) into the second term within the square brackets of equation (19) to get:

$$2(m_2 + \theta\Delta_m) - \frac{t}{\lambda} - \frac{1}{(\mu + \frac{1}{4}(-\lambda - 2\mu + \sqrt{(\lambda + 2\mu)^2 - \frac{8\lambda^2}{t(-\lambda + \mu)}}))^2}$$

(21)

To find out how the term reacts to increases in the content request rate we add random values to the other variables that maintain the assumptions that were made in chapter 3. The figure has been plotted with $m_2 = 0.5$, $\theta = 0.5$, $t = 0.5$, $\Delta_m = 0.2$ and $\mu = 5$. This is to maintain the assumptions that $m_1 \geq m_2 \geq 0$, and $\mu > \frac{3\lambda}{2}$ that are mentioned in chapter 3.

In Figure 11 you can see the results of the equation when the content request rate is increasing.

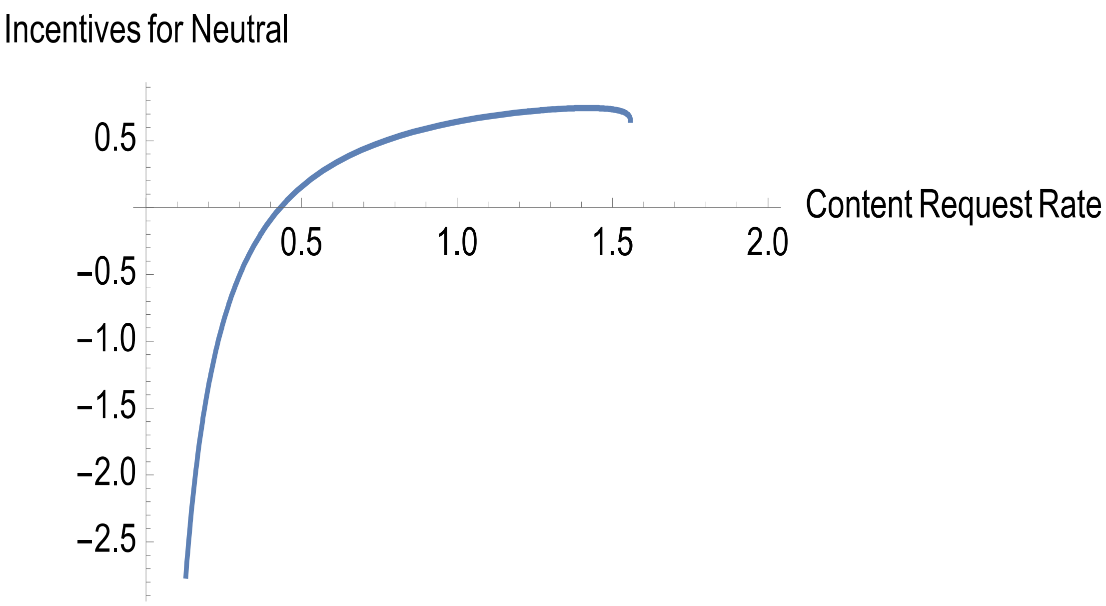

Figure 11: Incentives to invest for the different regimes as the content request rate increases

As we can see in Figure 11 the x-axis shows the content request rate increasing and the y-axis shows the incentive to invest in the neutral network when y is positive and the incentive to invest in the discriminatory network when y is negative. Here we can see that when the content request rate is low the ISP would want to invest more under the discriminatory network, but that this quickly changes as the request rate increases. When the request rate exceeds a certain threshold, the ISP would rather invest under the neutral regime. The reason is that any increases in speed become less profitable as congestion worsens and consumers no longer have to take the wait time difference between the two content providers into account when choosing which provider to subscribe to. This reduces the profitability that CP1 has for paying for first priority making them want to pay less for priority. The rise in the content request rate when the net neutrality regulations were removed might be one of the explanations of why investments fell in this period, but it is hard to say how large this effect is on the fall.

We have now looked at how investment fall might have been caused by some of the variables and how realistic these are, but what limitations does this model suffer under?

Choi and Kim's (2010) model have limitations in how realistic it is in its predictions with its biggest being that it only looks at a monopolistic ISP with two competing CPs that does not allow for direct pricing between the end consumers and the CPs. There are arguments that a monopolistic ISP is not an unrealistic assumption to make as Wired could report in 2014 that the ISPs in the U.S. were getting larger as there had been several mergers in the last few decades. This makes it a reasonable assumption as residential consumers have limited choice in Internet service providers and switching providers comes at a cost that consumers have to take into account (McMillan 2014).

Something else that the model does not take into account is the rising number of large ISPs that have bought up or started competing directly with content providers themselves like AT&T's purchase of Time Warner and through them the streaming site HBO. This is a more recent trend, so it is not surprising that the model does not include this (Sherman 2018). The ISPs incentive to invest might then change if it wants to prioritize its own content over competitors, meaning that it might want to speed up services it owns while slowing down others even as it loses out on the rent that it can receive for priority access.

The model also does not open for direct payment between the end consumers of content and content providers. This is a weakness as subscription fees have become more common online and is something that would affect how consumers choose between the content providers and in how much the ISPs can charge the consumers for Internet access (Simon & Graves 2019).

The model does also not take into account that net neutrality regulations can vary in strength as Gans (2014) found that this has a significant impact in how the regulations affect the investment incentives of Internet service providers.

8.0 Conclusion

This thesis has looked at how net neutrality regulations affect the investment incentives of Internet service providers by using the 2018 removal of the regulations in the U.S. as a way to examine the effect that the regulations had on Internet service providers. And, to see if the arguments that Internet service providers would invest more if not under net neutrality regulations that were made by opponents of net neutrality was true.

While several voices have argued over net neutrality regulations in the United States and its effect on Internet service provider's investment incentives, few empirical studies have been done and the ones that have been done show conflicting results. While the FCC (2018) argued that the removal of the 2015 net neutrality regulations would cause an increase in investment I have found little proof of this. The results that this thesis have found show no support that the removal of net neutrality led to an increase in investment but found rather a decrease. Using the model theorized by Choi and Kim (2010) this reduction might be explained by ISPs lack of motivation in investing in capacity expansion as any increase in speed will lower the CPs willingness to pay to achieve priority on their content as well as an effect of increased content request rate, high bargaining power and low product differentiation. But it is difficult to fully explain the results of this analysis as the effect that we have found might be over- or underestimated due to the limited time span as well as data. To conclude on the actual effect that the net neutrality regulations had on ISP' investment incentives more data is required and a longer treatment period to draw any definitive conclusion.

References

Alsop, T. (2022) Total revenue from telecommunication services in the United States from 1998 to 2020 (in billion U.S. dollars) Statista. Available at https://www.statista.com/statistics/185217/total-revenues-with-telecommunication-services-in-the-united-states-since-1998/. Downloaded 01.05.2022

Angrist, J. D. & Pischke, J. (2015) «Mastering metrics: the path from cause to effect» Princeton University Press, Princeton and Oxford

BEREC (2020) BEREC guidelines on the implementation of the open internet regulation. Body of European Regulators for Electronic Communications (BEREC). BoR (20) 112. Available at https://berec.europa.eu/eng/news_consultations/Closed_Public_Consultations/2019/6309-public-consultation-on-the-document-on-berec-guidelines-on-the-implementation-of-the-open-internet-regulation. Downloaded 31.05.2022

BEREC (2021) Press release – BEREC will update Guidelines following the Court of Justice rulings on zero-rating, publishers recently adopted reports and calls for stakeholder's input. Body of European Regulators for Electronic Communications (BEREC). BoR (21) 151. Available at https://berec.europa.eu/eng/document_register/subject_matter/berec/press_releases/10047-press-release-berec-will-update-guidelines-following-the-court-of-justice-rulings-on-zero-rating-publishes-recently-adopted-reports-and-calls-for-stakeholders-input. Downloaded 31.05.2022

Bohlin, E. (2020) Expression of concern: Testing the economics of the net neutrality debate. Telecommunications Policy 44(5) (June 2020) 101869

Bourreau, M., Kourandi, F., & Valletti, T. (2015) Net neutrality with Competing Internet Platforms. The Journal of Industrial Economics, 63(1), 30-73.

Brogan, P. (2016) Broadband investment ticked down in 2015. USTelecom Research Brief. 31.10.2016

Brogan, P. (2017) Broadband continued trending down in 2016. USTelecom Research Brief. 18.10.2017

Brogan, P. (2019) U.S. Broadband Investment Contined Upswing in 2018. USTelecom Research Brief. 31.07.2019

Buckley, S. (2017) AT&T and CenturyLink say the FCC Title II reversal will spur new investment. Fierce Telecom. Available at https://www.fiercetelecom.com/telecom/at-t-and-centurylink-say-fcc-title-ii-reversal-will-spur-new-investment. Downloaded 26.05.2022

Choi, P, & Kim, B.C. (2010) Net neutrality and investment incentives. RAND Journal of Economics, 41, 446-471

Cohen, D. L. (2017) Comcast Supports Net Neutrality and Reversal of Title II Classification. Title II is Not Net Neutrality. Comcast. Available at https://corporate.comcast.com/comcast-voices/comcast-supports-net-neutrality-and-reversal-of-title-ii-classification-title-ii-is-not-net-neutrality Downloaded 26.05.2022

Collins, Keith (2018) Net Neutrality has officially been repealed. Here's how that could affect you. New York Times (Online), New York: New York Times Company. Available at https://www.nytimes.com/2018/06/11/technology/net-neutrality-repeal.html. Downloaded 09.11.2021

Crews Jr., C. W. (2014) Court Rules against Net Neutrality in Verizon V. FCC. Forbes. Available at https://www.forbes.com/sites/waynecrews/2014/01/14/court-rules-against-net-neutrality-in-verizon-v-fcc/?sh=386bfa052ed8 . Downloaded 19.05.2022

Eggerton, J. (2017) Title II Rollback Reaction Rolls On. NextTV. Available at https://www.nexttv.com/news/title-ii-rollback-reaction-rolls-165963. Downloaded 30.05.2022

ETNO (2016) State of Digital Communications 2016. European Telecommunications Network Operators' Association (ETNO).

ETNO (2018) State of Digital Communications 2018. European Telecommunications Network Operators' Association (ETNO).

ETNO (2021) State of Digital Communications 2021. European Telecommunications Network Operators' Association (ETNO).

ETNO (2022) State of Digital Communications 2022. European Telecommunications Network Operators' Association (ETNO).

Faulhaber, G. R. (2011) Economics of Net Neutrality: A Review. Communications & Convergence Review, 3(1) (2011), pp. 53-64

FCC (2010) In the matter of preserving the open industry broadband practices. FCC 10-201 Dec 23, 2010

FCC (2015) FCC Releases Open Internet Report and Order on Demand, Declaratory Ruling, and Order. FCC 15-24 March 12, 2015

FCC (2018) In the Matter of Restoring Internet Freedom. Federal Communications Commission (FCC). FCC 17-166.

FCC (2020) Broadband speed guide. FCC. Available at https://www.fcc.gov/consumers/guides/broadband-speed-guide Downloaded 25.05.2022

FCC (2021) Common Carrier Filing Requirements - Information for Firms Providing Telecommunications Services. FCC. 18.05.2021. Available at https://www.fcc.gov/reports-research/guides/common-carrier-filing-requirements-information-firms-providing-telecommunications-services#form499A Downloaded 20.04.2022

Finley, K. (2020) The WIRED Guide to Net Neutrality. WIRED. Available at https://www.wired.com/story/guide-net-neutrality/. Downloaded at 17.05.2022

Ford, G. S. (2017) NN, reclassification and investment: A counterfactual analysis. Perspectives. Phoenix Center for advanced Legal & Economic Public Policy Studies Phoenix Center Perspectives 17-02

Ford, G.S. (2019) Net Neutrality and Investment in the US: A Review of Evidence form the 2018 Restoring Internet Freedom Order. Review of Network Economics. 17 (3), 175-205

Ford, G. S. (2021) Testing the Economics of the Net Neutrality debate: A comment. Telecommunications Policy 45(5):102137

Free Press (2017) Untitled table. Free Press. Available at https://www.freepress.net/sites/default/files/2018-06/fpaf_broadband_investment_basics.pdf. Downloaded 10.11.2021

Gadringer, S. (2020) Network neutrality in the European Union: A communications policy process analysis. Digital Technology, Culture and Society. 4(2): The Internet and the EU Market.

Gans, J. S. (2014) Weak versus strong net neutrality. Journal of Regulatory Economics. 47, 183-200 (2015)

Garrett, T., Setenareski, L. E., Peres, L.M., Bona, L.C.E., & Duarte Jr., E.P. (2022) A survey of Network Neutrality regulations worldwide. Computer Law & Security Review. 44 (April) 105654.

Goree, S. (2020) Yes, websites are starting to look more similar. The Conversation. Available at https://theconversation.com/yes-websites-really-are-starting-to-look-more-similar-136484. Downloaded 1.06.2022

Greenstein, S., Martin, P., & Valletti, T. (2016) Net Neutrality: A fast lane to understanding the trade-offs. The Journal of Economic Perspectives, 30(2) (2016), 127-149. Spring 2016

Hanck, C., Arnold, M., Gerber, A., & Schmelzer, M. (2021) Introduction to econometrics with R. University of Duisburg-Essen. Available at https://www.econometrics-with-r.org/index.html. Downloaded 10.04.2022

Hooton, C. A. (2017) An empirical investigation of the impacts of NN Report. Internet Association.

Hooton, C. A. (2020) Testing the economics of the net neutrality debate. Telecommunications Policy 44(2020) 101869

Kelly, M. (2021) Biden appoints Jessica Rosenworcel to lead the FCC. The Verge. Available at https://www.theverge.com/2021/10/26/22746223/net-neutrality-fcc-jessica-rosenworcel-chair-gigi-sohn-ajit-pai-broadband. Downloaded 23.05.2022

Kovac, A. (2017) The Effect of Title II Classification on Wireless Investment. Georgetown Center for Business and Public Policy. Available at https://cbpp.georgetown.edu/publications/publications-policy-papers/. Downloaded 15.05.2022

Litan, R.E. & Singer, H.J. (2007) Unintended consequences of Net Neutrality. Journal on Telecommunications and High Technology Law, 5 (2006-2007) (2007), pp. 533-572

McMillan, R. (2014) What everyone gets wrong int the debate over net neutrality Wired. Available at https://www.wired.com/2014/06/net-neutrality-missing/. Downloaded 27.05.2022

Nilsen, E. (2019) Why the Senate is blocking a new net neutrality bill, a year after trying to save it. Vox (Online). Available at https://www.vox.com/2019/4/10/18302186/net-neutrality-house-bill-senate. Downloaded 10.04.2022

O'Dea, S. (2022) Number of Broadband Internet subscriber in the United States from 1st quarter 2011 to 3rd quarter 2021, by cable provider. Statista. Available at https://www.statista.com/statistics/217348/us-broadband-internet-susbcribers-by-cable-provider/. Downloaded 31.05.2022

Pew Research Center (2021) Internet/Broadband Fact Sheet. Pew Research Center. Available at https://www.pewresearch.org/internet/fact-sheet/internet-broadband/. Downloaded 31.05.2022

Post- og Teletilsynet (2009) Nettnøytralitet: Retningslinjer for nøytralitet på Internett. Post- og Teletilsynet. Versjon 1.0.

Reardon, M. (2022) Net neutrality will make a comeback in 2022. CNET. Available at https://www.cnet.com/home/internet/net-neutrality-will-make-a-comeback-again-in-2022/. Downloaded 23.05.2022

Reglitz, M. (2020) Internet access is a necessity not a luxury - it should be a basic right. University of Birmingham. Available at https://www.birmingham.ac.uk/news/2020/internet-access-is-a-necessity-not-a-luxury-it-should-be-a-basic-right. Downloaded 26.05.2022

Robuck, M. (2020) Due to COVID-19, broadband usage spikes 47% in Q1, nearly surpassing all of 2020's projections-report. Fierce Telecom. Available at https://www.fiercetelecom.com/operators/due-to-covid-19-broadband-usage-spikes-47-q1-nearly-surpassing-all-2020-s-projections. Downloaded 31.05.2022.

Romm, T. (2010) GOP lawmakers threaten to repeal Net Neutrality. Politico (Online), Virgina: Politico LLC. Dec 12, 2010

Rundfunk und Telekom Regulierungs-GMBH (2021) EU net neutrality regulation. Rundfunk und Telekom Regulierungs-GMBH. Nov 12, 2021

Schultz, C. (2014) What was internet like the day Facebook was born? Smithsonian Magazine. Available at https://www.smithsonianmag.com/smart-news/what-was-internet-day-facebook-was-born-180949597/. Downloaded 26.05.2022

Sherman, A. (2018) How Netflix sent the biggest media companies into a frenzy and why Netflix thinks some are getting it wrong. CNBC. Available at https://www.cnbc.com/2018/06/13/netflix-why-att-bought-time-warner-and-comcast-and-disney-want-fox.html. Downloaded 26.05.2022

Simon, F. & Graves, L. (2019) Across seven countries, the average price for paywalled news is about $15.75/month. Niemen Foundation. Available at https://www.niemanlab.org/2019/05/across-seven-countries-the-average-price-for-paywalled-news-is-about-15-75-month/. Downloaded 01.06.2022

Statista (2022) Total revenue from telecommunication services in the United States from 1998 to 2020 (in billion U.S. dollars). Statista. Available at https://www.statista.com/statistics/185217/total-revenues-with-telecommunication-services-in-the-united-states-since-1998/ . Downloaded 10.04.2022

Stock, J.H. & Watson, M.W. (2020) Introduction to Econometrics, 4th Edition. Pearson Education, Malaysia. 2020

Sørensen, F. (2020) Europeisk regulering av nettnøytralitet. NKOM. Available at https://www.nkom.no/internett/nettnoytralitet/europeisk-regulering-av-nettnoytralitet. Downloaded 23.05.2022

Telenor (2018) Endringer i Telenors konsernledelse og nye ledere i Thailand og Myanmar. Telenor. Available at https://www.telenor.com/media/newsroom/archive/endringer-i-telenors-konsernledelse-og-nye-ledere-i-thailand-og-myanmar/. Downloaded 02.03.2022

USTelecom (2021) 2020 Broadband Capex Report. USTelecom: The Broadband Association. Available at https://www.ustelecom.org/research/2020-broadband-capex-report/. Downloaded 10.04.2022

Vogels, E. A. (2021) Some digital divides persist between rural, urban, and suburban America. Pew Research Center. Available at https://www.pewresearch.org/fact-tank/2021/08/19/some-digital-divides-persist-between-rural-urban-and-suburban-america/. Downloaded 20.05.2022

World Wide Web Foundation (2015) Net neutrality in Europe: a statement from Sir Tim Berners-Lee. World Wide Web Foundation. Available at https://webfoundation.org/2015/10/net-neutrality-in-europe-a-statement-from-sir-tim-berners-lee/. Downloaded 31.05.2022

Wu, T. (2003) Network neutrality, broadband discrimination. Journal on Telecommunications and High Technology Law, 2, 141-178

Wu, T (2006) Why have a telecommunications law-anti-discrimination norms in Communications. Journal on Telecommunications and High Technology La, 5(2006) pp.15-46